

NATURAL PHILOSOPHY

Improv'd by DRUGÉ DONATION

# NEW EXPERIMENTS.

TOUCHING

The *Mercurial Weather-Glass*, the *Hygro-scope*, *Eclipses*, *Conjunctions* of  
SATURN and JUPITER.

BY NEW EXPERIMENTS,

Touching the *Pressure of Fluids*, the *Diving-Bell*, and  
all the curiosities thereof.

To which is added,

Some *New Observations*, and *Experiments*, lately made of  
several kinds.

TOGETHER,

With a true RELATION of an *Evil Spirit*, which troubled a *Mans* Family  
for many days.

LASTLY,

There is a large DISCOURSE, of *anent Coal*, *Coal-fires*, *Dips*, *Risings*, and  
*Streets* of *Coal*, *Levels*, *Running of Mines*, *Gates*, *Dikes*, *Damps*, and *Wild-fire*.

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By G. S.

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*Ars longa, vita brevis.*

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Printed in the Year, 1683.

And are to be sold by *Gideon Schaw* Bookseller, at the  
Sign of the Bible, in the *Parliament-Cloſt*, in *Edinburgh*.

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To the Right Honourable

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**S<sup>r</sup>. JAMES FLEMING,**  
**Lord Provost of EDINBURGH,**

*George Drumond, David Lindsay, James Nicolson, and GEORGE SINCLAR Bailiffs, Archibald Hamilton, Dean of Gild, Thomas Young, Thesaurer, William Borthwick, Deacon Conveener, and remanent Members of the Honourable Council of the said Burgh; In all Humility offers and dedicates this Philosophical Transaction, GEORGE SINCLAR Professor of Philosophy and Mathematicks.*

May it please Your Lordship, and the Honourable Senate,

**I** Present you with a mean Oblation, less than the Widows Mite, but with a willing mind. 'Tis all I can afford at present. *Farre licabit, qui non habet, thus: who wants Frankincense, must sacrifice with Bear-meal. I have sometimes offered more to others, who were not so deservng. I still remember how kindly the Council treated me for some Tears ago, when I taught the Mathematicks at Edinburgh; and what a singular Obligation, they conferred upon me after, when I was employed to search out a well, which by good Providence I lighted upon, which is now a Well-spring of Happiness to the Good-Town. I made several Observations, with a most accurate, and exact Level; but especially one from the highest Ground in the Castle, in the Evening towards the Fountain, by the help of a Light there, on the 29. of May, 1674. which gave insalible assurance to the Magistrates, that the Source was 200. Foot higher than the Weigh-house, and great entourage to the Council to begin the work. It is registrate in Scripture, as one of the great Acts of Hezekiah, that he made a Cistern, and a Conduit, and brought water into the City of Jerusalem. This work will be extant among the Annals and Chronicles of the City, of things done from Year to Year, to all Generations, which is the glory also of the succeeding Magistrates. But your wisdom and prudence in governing the City, and composing all Differences, and settling all Matters every day so happily, is of far greater moment.*

*This Transaction explains the Weather-Glass, and Hygroscope, which are in great esteem, even among Kings, and Princes. His Royal Highness put no small value upon that which I presented to Him. Non equidem tali me dignor honore.*

*I now crave pardon, that I have adventured to prefix your Names to the Frontispice of this mean Pamphlet, between which, and your incomparable Merits, there is no proportion. All I can do, is to pray, that your Lordship and Council may live to be, as you are, the glory and credit of the Place, and that you may slowly, yet surely exchange at last, this Mortality with Immortal Life. This I fervently wish, while I am*

Your Honours most humble, and much obliged Servant,

Leith, January 9. 1683.

GEORGE SINCLAR.

## The Explanation of the Weather-Glass.

**I** Have set down the Theory of the Weather after this manner. In the first, and upmost Station, thirty Inch and a half, above the Cistern, is *Long Fair*, or *Most pleasant weather*, as the Poet sings,

Totus ille dies, & qui nascentur ab illo,  
Exactum ad mensuram, pluvia ventisque carebunt.

*This day and all, which after it remain,  
For thirty days, shall want both Wind and Rain.*

The Metal being at this height, which I rather find to be in Winter, than in Summer, the Heavens are clear: yet sometimes covered with dry and gray Clouds, but not the least appearance of Rain. Nothing for several days after, but settled calm Weather, as dry and hard Frost in Winter, with a clear Sky: sometimes the Air most pure, and clear without Frost. Here it was upon Thursday, *October 26.* 'Tis seldom so high, because we in this Countrey have not often, a most pure, and clear Air; as in *France*, and other parts of the World: If the Metal ascend to this Station, it is an evident token, that the Glass, is right mounted, and adjusted.

I call the second Station, which is half an Inch lower, *Fair*, or *Dry and Fair*.

Ecce serenato clarum jubar emicat aëre,  
Purgataque nitet discussis cubibus aëther.

*Behold a Ray, that clear breaks forth from yonst Heavens  
And purged Sky doth shew, all clouds assu'd that's born.*

The Quick-silver being at this Station, the Weather is good; but not so settled, especially in the Winter-season. I have oftentimes observed a small thin shewer of Rain to fall, for some Hours together, from the lowest Region of the Air, as a thick Dew or Mist, but Immediately after, the Day became Clear and Fair, the Air being under a strong disposition to be so.

The third Station, half an Inch lower is *Changeable*, sometimes Fair, sometimes Foul, sometimes Frost, sometimes Thaw, sometimes Sleet, sometimes Snow, sometimes Wind, sometimes Calm.

Nunc pluit, & claret, nunc Jovis aethere surgit.

*Sometimes Jovial Jove, doth wing the Clouds for Rain,  
Sometimes fair Jove, appears in Heavens again,*

The fourth Station is *Rain*, or *Rainy Weather*; not that it Rains always, but that there is a strong inclination in the Air, to be Rain.

Madida Notus evolat alis,  
Terribilem picea teclus caligine vultum,  
Barba gravis nimbi, ovis sicut unda et capillis.

*Out flies the South, with drooping Wings, who fronts  
His dreadful aspect in the piny Clouds,  
His whitest air streams; his beard big-furrows with Showers  
Mists bind his brow, Rain from his bosom pours,*

I call the fifth Station, *Much Rain*, or *Very Foul*, as in the Summer, or Winter-time, when Rain is accompanied with strong S.W. and W. Winds. This is bad Weather indeed, both by Sea and Land.

Et tenis funduntur ab aethere nimbis,  
Ecce carent largi, volutus nubibus, imbre  
Inque irem credas totum descendere coelum.

*Thick storms of Rain, are poured from the Heavens,  
Whither dark Victims, and his percing Beams,  
From Clouds dissolved, great showers did fall,  
Some thought the Heavens to Sea, were tumbled all.*

To this Station did the Mercury fall down, on Monday, *November 6.* and Sunday night, *November 19.* being two Inch lower, than *October 26.*

The sixth Station is *Stormy*, the worst of Weather in this Country.

Tum mihi caeruleus, supra caput assit imber,  
Noctem Hyememque ferens, & inhorruit unda tonitruis.

*A purple shower did Canopy my head,  
Dark Winter came, and waves grew black indeed.*

I have

I have subjoyned in the last place *Tempests*, or *Hirricanus*, which do not fall out in this Country. They are lively described by the Poet.

----- *Ac ventis, ventis agmine is cito,  
Qua data porta vocant, et terrarum turbine perfaror,  
Introuere mari, toruque a sedibus imis.  
Una, Barigis, Noisique mont, creneque procel'is  
Africis, & vastis voluunt ad littora fudius.  
Tempeſtas sine more furit, confutrage crenifunt.  
Ardua terrarum, compique & litorea circum.*

----- *Winds as his malicious Bands  
Force their own way, and shunder through the strands,  
They take the Sea, Euros and Notus reaves,  
And Romy Africa from deepſt caves,  
When Tempeſt ſwags, and Joves great Canons roar,  
The Mountains quake, the Plains, and every Shore.*

The first Rule is, the further up the Metal goes, the Weather inclines to be the Fairer, and the further it falls down, it inclines to be the Foulter. Secondly, When it is heighth, Fair Weather is universal, when it is lowest, Foul Weather is universal. Thirdly, 'Tis not so much Fair or Foul Weather actually, which influences the Quick-silver, as it is the disposition, and inclination of the Weather, to be Fair, or Foul. Note, That N. E. and E. Winds, even when Rain, do raise the Mercury, and keep it up sometimes beyond ordinary.

And as it shews the nature of the Weather, so it foretells; which is the great excellency of it, sometimes a day, sometimes two, sometimes three or four, before any change of Weather come. The Metal rises and falls quickly, when Fair or Foul Weather is nigh at hand: It doth not so much foretell Winds, as it is actually influenced by them, when they blow, in causing the Metal subside and fall down. 'Tis said, that the Ladies and Gentlewomen at London, do Apparel themselves in the Morning, by the *Weather-Glass*. Whatever be in this, 'tis certain, that when a Man riseth in the Morning, he may know infallibly, what sort of Weather, will fall out ere Night. It is not possible to make it unerring, unless it be mounted, and set up by a skillful Hand, which few or none can do. The inclosed *weather-Glasses*, are Ten Dallers, the open ones Thirty Shillings, which are as true. None from Abroad are so accurately made. Neither any such are sold, at so easie a rate. They may be transported, and carried to any part of the Country, and there set up, by my Directions.

## The Explanation of the Hygroscope.

**T**His second is a curious Invention, which I call the *Hygroscope*. The Name is made up of two Greek words, *Hygros* Wet, and *Scopeo* to view or consider: because we know by it, the several degrees of *moisture*, and *dryness* in the Air. It is meant to look upon, being but the *Awin*, and *Beard* of a Grain of *Oats*. It is Twisted, and Twined by Nature, as the *Lute String*, or a *Silk Cord* is twined by Art. It is secured within a round Box, whose Inside is divided into 24, equal parts. There is affixed to the top of it, a small slender Glass-Index, which goes about with the *Awin*, as it is altered with the *moisture*, or *dryness* of the Air. The motion is *direct*, or right about, following the course of the Sun, with *moisture*, and *retrograde*, or left about, with *dryness*. It is likewise *stationary*, or *standing*, when the Air is settled, as to *wetness*, or *dry-*

*ness*. It is of all of all things, in the Universe, so far as I know, most affected and sensible of *humidity* and *secity*. Many curious Philosophical Questions do arise from its several Operations, which would trouble *Oedipus* himself, to resolve. I have found the Index, from Wet Air in extremity, to Dry Air in extremity, make six Revolutions. For this cause, I have contrived a little *Broad*, with six Circles upon it, or rather Spirals, divided equally into 24. parts, as the inside of the Box is, by the help of which, a Man may trace the motion of it, all the Year over, most easily, whether it be *Direct*, or *Retrograde*. You will find these advantages by it. *wet Air in extremity*, *Dry Air in extremity*, *Air equally moist and dry*, *wet Air*, *Dry Air*. It discovers the least difference of Air between one Room and another. It is much influenced with Winds from the North, especially in Frost, which make it

*Retrgrade*, and with Winds from the South, which make it *Direſt*, and move right about. In a Year's time, it makes ſeveral Revolutions. The motion is moſt ſenſible, for ſometimes in one Night, it will alter 90. Degrees, or the fourth part of a Circle. It not only ſhews the preſent temperament of the Air, which is a great advantage, but foretels. Nay, which is admirable, I have found it ſometimes foretel *Fair Weather*, when it was actually *Raſing*. It keeps a correſpondence with the *Weather-Glaſs*. There is great difficulty to know what Revolution it is under, from *Wet Air* in extremity, or from *Dry Air* in extremity, for fixing the *Brass-Pin* in its own proper Circle. The Hoof or Hool, of the *Mouth-Pea*, (as we call it) or the *wild Vetch*, will make a *Hygroſcope*, but it is ſomewhat dull and ſlow, and goes not ſo oft about, yet very ſenſible of the *Wetneſs*, and *Dryneſs* of the Air. When the Index of the *Hygroſcope*, is altered by the Weather, it keeps not a continued motion, but ſometimes moves backward, and ſometimes forward; yet at length perfects its courſe right about, in ſo many Months, and returns again in ſo many. Among the many difficulties which occur, this is one, What is the reaſon, why the *Awin* goes always right about with *Moſture*, and left about with *Dryneſs*? To ſay, that it is ſo ordered by Nature, is ridiculous. The ſame difficulty we find in the Shells of *Snails*, whoſe Screw, and Spiral line, goes right about, with the Sun, and in the Shells of *Sea-Snails*, commonly called *Buckles*. Some affirm, that upon the South of the *Line*, the Shells of theſe Creatures, are ſcrewed left about, which is worthy of obſervation. 'Tis eaſie to give the reaſon, why a *Lute String* turns about ſuch a way with *Moſture*; becauſe, while it was twined by the Ariſt, the *wheel* or *Spindle* went ſuch a way about, where-with he twiſted it. But who can ſay the like of the *Awin*, ſeing the great Ariſt is *GOD*, and Nature, whoſe working and manner of working is unknown to us. If it be asked; What way goes about the Hool of the *wild Vetch*? I anſwer, which is a notable Speculation. The one Hool, goes right about with the Sun, by *Moſture*, as the

*Awin* doth, and conſequently left about, with *Dryneſs*. But the other goes right about with *Dryneſs*, and left about with *Moſture*, contrary to the motion of its fellow Hool. This is ſeen ſenſibly, by holding them nigh the Fire. The ſame holds true, in the two Hooks of the *Right Pea-cod*. I ſuppoſe that the Hooks of *Brom-leed*, may do the like. Another Experiment I made with the *Hygroſcope*, in placing it, within the Receiver of the *Air-pump*. At the very fiſt Exauſtion of the Air, the Index moved left about moſt ſenſibly, and by the ſeveral Exauſtions, which were made one after another, it advanced, half a Circle about. It had been eaſie to have made it go right round once, if I had continued *Pumping*. Here is a *Phænomenon* to beſolved, and well worthy the pains of a *Virtuoſo*. But becauſe ſome may think, I have ſpoken too much of a thing of ſmall concern, I ſhall therefore ſay but one word or two more. That even upon the obſcureſt, and meaneſt of the Creatures, the *LORD* hath impreſ'd an Indeliſible Character, of His Wiſdom and Skill. Though we cannot well know, for what uſe and end, the *Oat-Grain* hath an *Awin*, and why it is twiſted, yet we muſt remember, that *GOD*, and Nature, never made any thing in vain. Do not undervalue it, becauſe it is meanly ſet out; for there is in it a Pearl of great price; *Chriſtopherus Starminus* a German, a great *Virtuoſo*, and famous *Mathematician*, makes honourable mention of it, in his Writings, which he hath taken from my *Arts Nova & Magna*, as he hath done many other Curioſities, and publiſhed them to the World, not as his own Inventions, but as mine: which by the way, gives a notable check to my old Adverſaries, who with the *Bedells* Gown about their heads, endeavour'd to make the World, in their beggarly Pamphlet believe, that all my Philoſophical Experiments were Untruths and Lies. *Sed non eſt remedium adverſus Sycophanta morſum*; there is no cure, or remedy againſt the biting of Slanderers. Mr. *Boyl* did not think ſo, as witneſs his Experiments touching Flame and Air. They are ſold for Six Shillings.



## A short account of the late Comets, and of some Eclipses.

**A**NNO 1652, An obscure Comet appeared in the beginning of Winter, seen in the fore-night, nigh to the Constellation of *Taurus*. It did not continue long; yet *Lilly* that old Astrologer made it very prodigious.

A second, far more glorious, appeared in the beginning of December, 1664. It rais'd before the Sun several Mornings, with a long Ray, pointing towards the West. First then, it was *Cometa Barbatius*, the Ray going before the Star. It had a very swift motion towards the West, inclining upward, till it came the length, to be in opposition to the Sun, on the 19. of December, where it appeared *Cometa Crinitus*, without a Ray. Being under a swift motion, it advanced more Westerly and upward, and was seen clearly upon Sunday night, December 29. with a long Ray, pointing towards the East, which made it *Cometa Caudatus*, the Train following the Star, and setting after the Sun. This made many believe, that there were two Comets. It vanished a little below the *Rams-head*, after it had continued from December 8. 1664, to February 8. 1665.

A third was seen, the same Year 1665, in March, and continued till the 7. of April.

A fourth was seen in the middle of April, 1677, about 11, a Clock at Night. It continued but a short time.

The fifth seen over all *Europe* with admiration, appeared first clearly to us, December 14. 1680. It continued till February 8. 1681.

The sixth Comet, was seen Thursday Night, August 17. 1682, in the North, about 11 a Clock at Night, in the second Foot of the *Great Bear*. It had a swift motion towards the West, declining from the North. It pass'd over above the back of the *Lion*, and under *Coma Berenices*, under *Arcturus*, crossing *Bootes* forefoot, towards the *Aequinoctial*, and thence towards the *Beam of the Ballance*.

Anno 1682, Saturday night February 11, about 11 a Clock, a prodigious Eclipse of

the *Moon*. The total darkness, continued an Hour and a half, measured by the *Pendulum Clock*. The Eclipse, was not only Total, but Central, that is to say, a straight Line might have been drawn almost, from the Centre of the *Moon*, throw the Centre of the *Earth*, to the Centre of the *Sun*. The *Moons* face was red as Blood, especially about the middle of the Eclipse. Compare it with *Joel* 2: 10. *Acts* 2: 19, 20. *Isa.* 13. 10. *Ezek.* 32: 7, 8. *Mat.* 24. 29. *Luk.* 21. 25.

Anno 1662, December first, all the seven Planets met in that one Sign of *Sagittarius*, the *Archer*.

Anno 1663, Friday October 9. A conjunction of *Saturn* and *Jupiter* in the 13. deg. of *Sagittarius*.

Anno 1651, April 23. *Mercury* did Eclipse the body of the *Sun*.

This Year 1682, a conjunction of *Saturn* and *Jupiter* in the Sign *Leo*, on the 23. of October, which is the fourth Conjunction, since they entered the fiery *Trigon*, which are *Sagittarius*, *Leo*, and *Taurus*.

Anno 1679, April 2. Two Suns seen in the Firmament, in the Fore-noon, in *East-Lothian*. Extraordinary Foul-Weather followed this *Perseid*.

Anno 1598, February 25. a total Eclipse of the *Sun*, so that the Stars were seen. It is to this day called the *Dark Saturday*.

Anno 1642, March 29, in the Fore-noon, a total Eclipse of the *Sun*, so that the Stars were seen likewise. It is commonly called the *Dark Monday*.

*Simſenes Philadelphus*, a devout Man, and learned *Astrologer*, writes in his Book, which he published Anno 1646, and dedicated to *Frederick King of Bohemia*, that there never happened, any great Change or Alteration, in any State or Kingdom, in *Europe*; but what hath been accompanied, with a Conjunction of *Saturn* and *Jupiter*, under some *Trigon* or other. And reckoning over all the ten Principallities and Dominions, which have been in *Britain*, since the Year of the World 3618, he comes at last to the Year 1603, in which, *Saturn* and *Jupiter*, after



they had returned into the *Fiery Triplicity*, being the seventh time from the Creation, fell in Conjunction in that *Fiery Sign Sagittary*, in the Month of *December*. Here he takes occasion, to mention King *James*, his succeeding to the Crown of *England* that year, of whom by the way, take this *Distichen*, or two Verses.

Cura Dei, vatumque labor, sapientia fecit.  
Pax quocunque mutavit, regna quaterna Polo.

Gods Care, the Ager With Peace, Prophets Palms,  
For Kingdoms sent, in Heaven a kingdom gains.

And shews, that this, which he calls *Regnum Scotorum*, the *Dominion* of the *Scots*, and tenth *Principalis*, was received, by these two superior Planets, in their Greatest Conjunction. Note, That these Conjunctions, are sometimes propitious, as this was. It was likewise favourable to the *Hollanders*, who were treated with a *Free State* Anno 1607. And concludes, with these remarkable words. *Et non jam expectanda est gravior aliqua mutatio in Britannia, nisi continuâ Coniunctione lucesset, siquidem Periodi huic regno transferint. Nam à primo Rege Bruto usque ad presentem annum elapsi sunt anni 1978.* That is, And now there is not any greater Change to be expected in *Britain*, but a continued Succession of the *Nearst in Blood*; for truly the *Periods* to these *Dominions* are gone, and past over. Because from the first King

*Brutus* to this present Year, there are past 1978 Years. This *Brutus* was the first King of the *Britains*, who began his Reign in the Year of the World 3618, under the *Aerial Trigon*, and Conjunction of *Saturn* and *Jupiter*, in the Sign *Gemini*.

For the better understanding, know that the twelve Signs are divided into four *Triplacities*, which are called by Astrologues *Trigons*. The first *Trigon*, is called the *Fiery Trigon*, which contains, *Aries*, *Leo*, and *Sagittarius*. The second is the *Earthy*, which contains, *Taurus*, *Virgo*, and *Capricorn*. The third is the *Aerial*, which contains, *Gemini*, *Libra*, and *Aquarius*. The fourth is the *Watery*, which contains, *Cancer*, *Scorpius*, and *Pisces*. If it happen, that *Saturn*, and *Jupiter* be in Conjunction this Year in *Leo*, there next Conjunction, will happen, twenty Years after, or truly, 19 Years, 315 Days, and 19 Hours after, in *Sagittarius*. From *Sagittarius* to *Aries*, from *Aries* to *Leo*, and so in round all 198 Years, and 236 Days passing, they make a *Transit* into a New *Trigon*, so that the Revolution of one *Trigon* consumes almost 200 Year. My Author speaking of that Conjunction, which fell out Anno 1643. in *Aries*, says, *Alicujus Imperii, vel Regni, revolutionem potendit.* It betokens a change in some Empire or Kingdom in *Europe*, which really came to pass after, as all know.

### A Journal of the late great Comet under the Latitude of 55. deg. 54. m. 30. s.

**O**N the 22. of November, 1680, It was first seen at *Plimouth*, in *England*, soon in the Morning. Upon the 24. of *Decem.* being Tuesday, It appeared first to us, in the Constellation called *Antinous*. This *Antinous*, was of the Country of *Bithynia*, who for his vallant deeds, was Canonized, and added to the number of the Gods, and placed in Heaven, in *Capricorn*, in which Sign the Sun at that time was, *dec. 3. m. 39.* This Comet had a Ray, which went straight up from it, about 60. Degrees in length. This Night, at 5. a Clock, it had 5. deg. of Altitude, above the Horizon.

The Ray was broader, and more spread out above, than below. In the Head was a clear Star, of a whitish colour. The middle of the Ray covered the lesser Star in the Gorge of the *Eagle*. The Poets feign, that this was the Bird, that flew up into Heaven with *Ganymedes*, whom *Jupiter* loved so dearly; for which good service, he placed the Bird among the Stars. Wednesday, *Decemb. 16:* at 5. a Clock at Night, the Blazing Star, seemed to be higher, by 3. degrees almost, and more Easterly. For this Night, the middle of the Ray, eclipsed the bright Star, in the neck of the *Eagle*, which is the greater, and more towards the East; but some-

what lower. The *Pinion* of the lowest Wing of the *Swan*, did terminate the extremity of the *Train*. On Thursday Morning following, about 5. a clock, the Ray was seen above the Horizon: at least much of it, not straight up, but sloping towards the North. At Night, December 16. about 5. a Clock, the Star had about 11. degrees of Altitude above the Horizon. At which time, the Ray had passed by, both the two forementioned Stars in the Neck of the *Eagle*, it being far more Easterly. It was not seen, till Sunday at Night, December 19. at which time, it was yet further up above the Horizon, the middle of the *Train*, covering the Constellation, called the *Delphin*. *Neptune* the god of the Sea, greatly desired, to match with *Amphitrite*, who being modest, and shame-faced, hid her self. After long search, he sent the *Delphin*, who found her out, for which good service, he placed this Fish in the Heaven. It was not seen till Decemb. 24. at which time in the Evening, it was past the *Aquator*, and had about 7. degrees of North Declination, and was in the 20. degree of *Aquarius*, not far from the Nose of *Pegasus*. The Night following, being Saturday, Decemb. 25. it was not seen. Sunday Decemb. 26. it was seen, at 5. a Clock, with 37. degrees of Altitude. The middle of the Ray, did cover the right Knee of *Pegasus*. The end did terminate in the very Zenith, between *Cassiopea*, and *Perseus*. After this the Star was not seen, till January 2. 1681. This Night the Ray, past thorow the Belly of *Pegasus*. *Perseus* did terminate the end of it. *Pegasus* the winged Horse, was bred of the blood of *Medusa*, after that *Perseus* had cut off her Head. *Bellerophon* made use of this Horse, and having performed some valiant deeds here on Earth, endeavoured to fly up to Heaven on his Back, but being amazed by looking down to the Earth far below him, he fell from his Saddle. *Pegasus*, notwithstanding continuing his Journey, came at last into Heaven, and there obtained a place among the Constellations. Monday January 3. the Comet was distant from *Andromeda* her head, about 4 degrees, but somewhat more Westerly. Upon Tuesday January 4. the Comet, was

what lower. January 5. being Wednesday, the Comet was within a degree and a half, of the Head of *Andromeda*, but a little lower, and more Westerly. Thursday January 6. the Comet was higher, than the Head of *Andromeda*, but more Easterly. The Ray passed thorow between the two bright Stars, in the Belt of *Andromeda*. *Perseus* did terminate the end of it. This Night, the Ray was 30. degrees long. Friday January 7. it was not seen. Saturday January 8. the Head of the Comet, was within one degree, of the Star, which is in the left Shoulder of *Andromeda*, but a little higher, and more Easterly. The Ray was 22. degrees extended. Sunday January 9. the Comet was yet higher, by one degree, and more Easterly, than the forefald Star. The bright Star in the South Foot of *Andromeda*, did terminate the end of the Ray. It was not seen, till Friday January 14. on which Night, it was about mid-way between the bright Star, in the Belt of *Andromeda*, and the point of the *Triangle*, but somewhat higher to the said bright Star. *Andromeda* was the Daughter of *Cepheus*, and *Cassiopea*, and the Wife of *Perseus*, who, by the favour of *Minerva*, was taken up into Heaven, and placed among the Constellations. Saturday January 15. the Comet was somewhat higher, than it was the Night foregoing. Tuesday Night January 18. it had this position with the *Triangle*, according to the first Figure. Thursday Night January 20. it had this position with the *Triangle*, according to the second Figure. Thursday Night January 27. it was thus placed, according to the third Figure, about one degree, and a half above the Eastmost Star in the Base of the *Triangle*. The Ray was about 8. degrees in length. The end of it, was bounded with the Eastside of *Medusa's* Head. The *Triangle* was placed in Heaven, in honour of the *Geometricians*, among whom, the *Triangle*, is of no small Importance. Others say, that it was placed there by *Mercury*, that the Head of the *Ram*, might be the better known.

Saturday Night January 29. the Comet, was in a right Line, with the first Star of *Artes*, and the bright Star in *Medusa's* Head. And in a right Line, with the Westmost

Star, in the Base, of the Triangle, and the *Pleiades*. It was the matter of 8. degrees distant from the East-most Star, in the Base of the Triangle, further up, and more Easterly.

*Persus*, the son of *Jupiter*, and *Danae*, kill'd the Monster *Medusa*, and cut off her Head. Her golden Hairs were turned into *Serpents* by *Minerva*, for polluting her

Temple with *Neptun*. Whosoever looked on her after this, were turned into Stones. *Persus*, falling into trouble of Mind, for killing accidentally, his Grand-father *Acisus*, was taken up into Heaven, by his Father *Jupiter*, and placed there, with *Medusa's* Head in the one Hand, and the Sword in the other.



Wednesday February 7, the Comet was scarce discernable, yet further up in the Heavens, and more towards the East, than before. Tuesday Night, February 8. being the last time, it was seen, nothing appeared distinctly, save a small short Ray. This Night, it had 20. degrees of North Latitude, from the *Ecliptick*. It had 46. degrees of Longitude, from the first point of *Aries*. It was distant from *Medusa's* Head, 5. degrees. It was distant 14. degrees, from the West-most Star, in the Base of the Triangle. It was 10. deg. 30. m. from the bright Star in *Andromida's* foot. It was 16. degrees, from the first Star in *Aries*. It was 17. deg.

30. m. from the *Pleiads*, or Seven Stars. It was in the 16. degree of *Taurus*. From December 14, 1680. until February 8, 1681. It had advanced, the matter of 120. degrees, in the Arch of a great Circle, following the order of the 12. Signs, from about the beginning of *Capricorn*, to the 16. of *Taurus*.

This perhaps, may be lyable to the *Pharisaick* Censure, of some *Mathematical Rabbi*; but let him first, be at as much pains, as I have been at in Observing; and next, let him make his Observations, as accurate, and true as these are, without an Observatory, and the help, of fit, and proper Instruments.

These are to give Advertisement, to all Ingenious Persons, who have found out, any New Inventions, or made any New Observations, of things Astronomical, of things in the Sea, in the Earth, above Ground or under. In a word, whatever may be useful, for the promoting of Natural Knowledge, and Learning, and profitable to others, let them be communicated to the Author of this Translation, a true Narration being made, he shall have them published, with accuracy, and satisfaction to himself.

Printed in the Year,

PræfVLſere DVo, res anno rara, plâneta,  
HeI nobis Miferis, IVngVntVr, In ore Leonis.

Vtben SatVrn in the beaſt's, to IoVe Coſides near,

TO THE  
R E A D E R.

Courteous Reader,



*I* Shall not detain thee in the entry with a long Preface, but give a short account of what is needful to be known, of the Cause, Occasion, and Matter of the following Treatise. After the publication of my last Piece, about the Weight and Pressure of the Air, I found it needful to treat of the Pressure of the Water, because of the near relation between the two: the operations, and effects of both depending almost upon the same Principles and Causes. And that there are many things, which cannot thoroughly be understood, of the Pressure of the Air, without the knowledge of the Pressure of the Water: therefore to make the first the more evident, I have spoken of the second: the effects and operations of Hydrostatical Experiments, being more conspicuous and sensible, than the effects and operations of the other.

The Occasion was some spare time I had now and then, for making some Trials: part whereof are published here; the rest being rather some productions of Reason, attentively exercised on that Subject; which notwithstanding may be called Experiments, though never actually tried, nor haply can be, because of some accidental impediments: yet supposing they were, I make it evident, that such and such Phenomena would follow, whence many necessary conclusions are inferred.

As for the subject matter, there are first, more than thirty Theorems in order to the Pressure of Fluid Bodies, as Air, Water, and Mercury, which in effect are nothing else, but so many conclusions rationally deduced from various and diverse effects of Aerostatical, Hydrostatical, and Hydrargyrostatical Experiments, which for the most part, I have tried myself.

There are next twenty Experiments briefly described, by their own  
distinct

## To the Reader.

*distinct Schematisms: their Phenomena, according to the Laws of the Hydrostaticks are salved, and several new conclusions inferred. A Proposal is likewise made of a more convenient Engine for Diving. Here, several difficulties are proposed, and answered, and all the obvious Phenomena of Diving explicated. If the Lead which sinks the Ark, be judged too weighty, and big, which may render it not so tractable, and likewise hinder the Ark from going so near to the ground, as is desirable, and in some measure stop the sight, (which troubles are (I suppose) incident to the Bell also) it may be reduced to a far less weight, and quantity, and the overplus being made square and thin pieces, may line the mouth of the Ark without, between P Q and L M, according to the Figure 25, or may be put to, or taken away at pleasure. The Bell may have likewise in stead of this troublesome Foot-board, a weighty Ring of Lead, or two, to go round about the orifice without, in form of a Girth, or Belt, which may slip off and on at pleasure, and will as conveniently sink it, as if it had a weight appended: the Foot-board then may be of any form, quantity, or weight you please.*

*There are thirdly some Miscellany Observations, the design of which is only Philosophical. Some of them are Experiments made with the Air-pump, which I have adventured to insert here, even though the Noble Mr. Boyl hath given an account of many. But because the Engine was offered to me by the Laird of Salton, a Gentleman of a choise Spirit, I could not, but in obedience to his commands make use of it, and shew him the Product. There are also two or three Observations in the close, as that of the Primum vivens in Animals: of the Aliment, and growth of plants: and of the motion of the Aliment in Trees. To all which is added a short History of Coal, which I hope will be acceptable to some; this so needful a subject, never being treated of before by any. In it, mention is made of things common to Coal in general, as Dipps, Risings, and Streeks. Next, of Gaes, or Dykes, which prove so troublesome sometimes to the working of Coal. Thirdly, of Damps, and Wild-fire. Next, a method is taught for trying of Grounds, where never any Coal was discovered before. And lastly, the manner how Levels, or Conduits under-ground, ought to be carried on, for draining the Coal, and freeing it of Water.*

*When*



## To the Reader.

*When this Book was first committed to the Press, I sent an intimation thereof to some of my friends, for their encouragement to it, a Practice now common, and commendable, which hath not wanted a considerable success, as witness the respect of many worthy persons, to whom I am obliged. But there is a Generation, that rather, than they will encourage any new Invention, set themselves by all means to detract from it, and the Authors of it: so grieved are they, that ought of this kind should fall into the hands of any, but their own. And therefore, if the Author shall give but the title of New to his Invention, though never so deservedly, they fly presently in his throat, like so many Wild Catts, studying either to Ridicule his work altogether. a trade that usually, the person of weakest abilities, and most empty heads, are better at, than learned men, like those Schollars, who being nimble in putting tricks, and impostures upon their Condisciples, were dolts, as to their Lesson, or else fall upon it with such snarling, and carping, as discover, neither ingenuity, nor ingeniousness, but a sore sickness, called Envy.*

*In the Intimation, I affirmed, that the Doctrine concerning the Weight, and Pressure of the Water was New. This one word, like a spark of Fire falling accidentally among Powder, hath been the occasion of so much debate. Their ground is, because they look upon the Hydrostaticks, as a Science long ago perfected, seeing Archimedes 2000 years ago hath demonstrat the Water to have a Pressure, and some others since, as Stevinus. They affirm likewise, that all the Theorems, and Experiments, that are here, are either deduceable from Archimedes, and Stevinus, or are the same with theirs. If these Gentlemen had suspended their judgment, till this Book had been published, I suspect they would not have spoken so confidently. For Archimedes his propositions, they are but few, and proven (as Mr Boyl saith) by no very easie demonstrations, which have more of Geometrical subtility, than usefulness in them. But these, which are here proposed, are not only useful, but evidently evicted by reason, and sensible Experiments, even to the meanest capacities. And though some of mine, may (perhaps) co-incide with some of his, which to me is but accidental, yet our way of procedour is toto Cœlo different. His way is more Speculative: this is more Practicall. His demonstrations*



## To the Reader.

are Geometrical : these are Physical. His propositions are but for the use of a few : these are for the use of all. His are not illustrated, and confirmed by Hydrostatical Experiments : these are.

Stevinus a late Writer keeps that same method. Yet I judge it easie to let see, even in the entry, how little cogent some of his demonstrations are, without derogating from such a Learned Man. He hath indeed some Pragmatical Examples ( as he calls them ) for illustrating some of his Geometrical Propositions, anent the Pressure of the Water, but I leave them to be considered by the judicious and understanding. Again, in this Method, I am yet as much different from others, who have written lately, as from these I have been speaking of. For, I not only treat of the Pressure of the Water, but takes in with it, the Pressure of the Air joynly ; since to explicate sufficiently the Phenomena of the Hydrostaticks, without it, it is impossible. And yet furdur, I not only counterpoise Air with Water, but Air with Mercury, and Water with Mercury, by which means several mysteries, and secrets in this Art, are discovered.

There are several Inventions found out of late in the Hydrostaticks, whose events and effects, cannot be clearly deduced from the grounds of Archimedes, and Stevinus, who had not that clear discovery ( for ought we know ) of the Pressure of the Air, that some now have, without which, these effects can never be sufficiently explained. And who doubts, but others afterwards, may make farder discoveries, and profit the world yet more, with their Inventions, then any have yet done. Is then the Hydrostaticks, a Science long ago perfected ? To this Pedantick Conceit, I must again oppose the judgment of Mr. Boyl, who saith moreover, that the usefulness of this part of Philosophy hath been scarce known any farder than by name, even to the generality of learned men.

But let us suppose, that the notion of the Pressure of the Water, is of an old date, even as old as the Flood ( for Noah surely knew, that the Pressure of the Water, would sustain the Ark ) and ( giving, but not granting ) that Archimedes 2000 years ago hath written all the Principles of the Hydrostaticks, doth this hinder any man now, from deducing new Conclusions from these old Principles ? But there is here, no such thing for neither in this, nor in my last Piece, are my

## To the Reader.

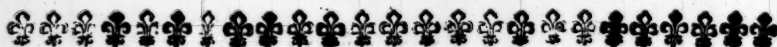
Adversaries able to trace me. 'Tis like the purposes would have been so much the better, if I had followed other mens foot steps: and it is like they might have been so much the worse. I doubt not, but I have lighted upon other mens thoughts in some things: and others writing on this same subject, who perhaps are my Antipodes, may fall upon mine. My Antagonists affirm, they are able to deduce all my Theorems, and the events of all my Experiments from the grounds of Archimedes and Stevinus. If they take not their word again, I hope they will do it; for now I put them to it. And though they should, (which I am not afraid they shall do in haste) yet they must prove next, that these Theorems and Conclusions, so deduced, are not new, which all their Logick will not prove. But what if we do more, (say they) even overthrow many of all your Aerostatical and Hydrostatical Experiments, in this, and in your last Peice? I give you liberty, and for your hire, a Guiny for each Theorem, or Experiment, you are able to ransack, in either of the two Books, though they come near to an hundred. But, ye must oblige your selves (my Masters) to do it with Reason, laying aside your Sophistry and Canina eloquentia. And this I offer, Reader, that I may reduce them, to a better humour, and encourage them to leave off flyting, and only use reason. Neither must they be like the Wasp, that only lights upon the sore place. But if they love to kindle any more fire, they will find me proof against it. If it burn them, it shall not heat me. Nevertheless, if they love to juik under deck, like Green-horns, having no courage in themselves, or confidence in their cause, they must excuse me, if at last, I write their names upon a Ticket, and bring them above deck. This is all I have to say, at present (Reader) and I bid thee farewell.

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## E R R A T A.

Page. 23. lin. 8. for weight read bensil. Page. 185. lin. 24. for EH, read FH. Page. 135. lin. 24. for 500. read 5000. Page. 307. lin. 26. read promoting. Page. 313. lin. 22. read reflection. Ibid. lin. 25. read elaborarint. Page. 317. lin. 3. read & magna.

Note, that in placing the Figures, the 12, that should have the fourth place in the third Plate, hath the first place in the fourth.



## Contents of the EXPERIMENTS.

**T**He first, second, and third Experiment, touching the *rising and falling down of Water in Tubs* of different sizes, son, why a man gripping with his fingers the *Torricellian Tub*, seems to find the weight of the Liquor within, and yet finds it not.

Pag. 37. 41. 44.

pag. 82. &c.

The fourth is a *Hydrostatical Experiment*, shewing the Reason why the *Mercurial Cylinder* rises, and falls, in the *Torricellian Experiment*, as it is carried up, or down thorow the *Air*. pag. 46. 50

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The sixth, touching the *suspension of Liquors in Pipes*, either closd or open above, not only of *Water* by *Water*, but of *Water* by *Air*. pag. 55. &c.

The twelfth, touching the reason, why a *Cylinder of Brass*, may be suspended by a *Surface* of *Water*, before it touch the bottom, that's 100 foot deep. pag. 101. &c.

The seventh, touching the *Cause of the suspension*, and *keeping up of Water in Weather-glasses*. pag. 59.

The thirteenth is, touching two plain heavy Bodies suspended under a *Water* 34 foot deep. pag. 109

The eighth, touching the reason, why a *Stone* weighs less in *Water* than in *Air*. pag. 71. &c.

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In Auctorem & Opus ENCOMIASTICON.

**Æ**theris expansi, vitrei Maris Antitalanton,  
Peroledos, Elasin, Fluidarum ritè videntes,  
Ingenio patefacta tuo, Magnalia rerum,  
Laudarant alacres Galli, Belgæque sagaces.  
Aggredieris nunc Arte Novâ, trutinare profundi  
Corpora, submersas quondam producere Gazas,  
Tollere demersis ingentia pondera Cupis.  
Gas fracidum in Cryptis ortum Fossoribus atrox,  
Submisso in Fundos Auræ renovante Flabello,  
Propulsare doces, Lithanthracumque Cavernæ  
Quæis foveantur Aquis, quo tendant, unde oriantur,  
Ordine quò circum Saxorum strata recumbant.  
Quodd benè capisti Naturæ cunctia foventis  
Munera solerti perge Illustrare Mathesi.

GEORGIUS HEPBURNUS, M. D.  
à Monachagro.

READER,



## To the Reader.

Reader,

**T**Hat thou mayest know, by one word more, how useful this part of *Philosophy* is, and how far t<sup>o</sup>m being a *Science long ago perfected*, take but this following proposal, lately, since my Book came to a close, communicated to me by a *Friend*, which, by his allowance, I have published, reserving the Answer to himself, the Author the cos.

Brother,

**B**y what you have published in your *Ars Nova & Magna*, and this Book, I have been led to this Invention, to beget within the Bowels of the Sea, a Power, or Force, which with great safety, and ease, shall bring up the greatest weight, that can be sunk therein: ad data quæcunque pondera demersa, in Maris visceribus Potentiam producere, quæ modo securo, & facili, è tundo cujusvis altitudinis ad summum, ipsa evehat. I drew a Letter one night, shewing the way how this might be done, which I communicated to you, that it might have been Printed with your Book: but after second thoughts, I judged it more meet to keep it up for a time, and that it should be set forth by way of Proposal only at the first, by

O'miston,  
May 20. 1682.

Your Brother,  
Mr. John Sinclair.

This *New Invention*, though *Hydrostatical*, is truly *Mechanical*, there being here a *Tonus* and a *Potentia*, whose operations depends upon *Mechanical Principles*. But in



several respects it is far more admirable, than the most part of the Mechanical Engines, which are look'd upon as stupendious. Many things, almost incredible, are reported of *Archimedes*, which he admirably brought about, by his Mechanical Powers; but I am confident, that by this *Invention*, as great a weight may be lifted, if not greater, as the Power of any Mechanical Faculty can be able to move. I know, the greatest conceivable weight, may be demonstrat, to be moved by the least conceivable Power, as the *Earth*, by the force of a mans hand. But how is it possible to contrive Artificially, an Engine for that purpose, which will do that by *Art*, which the demonstration makes evident by reason? It was thought a great enterprize, when *Pope Sixtus* the fifth, transported an *Obelisk*, which had been long since dedicated to the memory of *Julius Cesar*, from the left side of the *Ratican*, to a more eminent place, 100 foot distant; but to raise a Ship of 1000 Tun intirely, nay, a weight 100 times greater, is surely a far greater enterprize. This *Invention* is so much the more admirable, that not only by it, any supposed weight may be lifted, but from any deepness. Though this (perhaps) cannot be done Mechanically, because of some *Physical*, or *Moral* impediment, yet according to the *Laws* of the *Hydrostaticks* it can be demonstrat, and made evident by reason. And if this be, then surely, when the *Weight* is determinat, as the burdens of all *Ships* are, and the deepness known to be within so many fathoms, this *Invention* cannot but be successful.

Though the strength of *Mechanical Inventions*, may be multiplied, beyond the bounds of our *Imagination*, whereby the greatest *Weight*, may be moved, by the least *Power*; yet the *Wisdom* of *God*, hath thought it fit, so to confine that knowledge, that it cannot reach, how both

of them, can move with the same *quickness* and *speed*. For, if that were, the very works of Nature might be overturned. Therefore, it is observable, that when a great *Weight* is moved by a small *Power*, the motion of the one, is as much slower than the motion of the other, as the *Weight* of the one, exceeds the *Force* of the other. If it were possible *Mechanically* to move the *Earth* with the *Force* of a mans hand, the motion thereof would be as much slower, than the motion of the hand, as the *Weight* of the one, exceeds the *Force* of the other, which is a great disadvantage. And as the *Weight* and *Power* do thus differ, as to *swiftness*, and *slowness* in motion, so also, as to *Space*. For, by how much the *Power* is in it self less, than the *Weight*, by so much will the bounds or *Space*, the *Weight* moves thorow, be less than the *Space*, the *Power* goes thorow. If it were possible (keeping the same instance) to move the *Earth* with a mans hand, the *Space* thorow which it passeth, would differ as much from the *Space* the hand goes thorow, as the one exceeds the other; which is another disadvantage.

It may be thought, that if this *Invention* depend upon *Mechanical Principles*, it may be obnoxious to these abatements. I answer, though there be in it a *Pondus*, and a *Potentia*, a *Weight*, and a *Power*, this moving the other, yet it will evidently appear from Experience, that the motion of the one, is as swift as the motion of the other, and that the one moves as much *Space* and bounds in the same time, as the other, which is a great advantage. In this, it excells all the *Mechanical Powers*, and *Faculties*, that have ever yet been invented and practised. If any think, that such a device cannot be effectuat, without a considerable expence. I answer, the expence is so small, that I am ashamed to mention it. The method and manner of doing this, is most easie likewise. Neither ought this to be a ground, why any man should

should condemn it; since the most useful Inventions ordinarily are performed with the greatest facility.

As it commends this part of *Philosophy* to all ingenious *Spirits*, as most pleasant, and most profitable, so it gives a check to the *ignorant*, who look upon it as a *Science long ago perfected*.

In praise of the *AUTHOR*, and his *WORK*.

1.  
**W**hilst Infant- Art no further did pretend  
 Then to flat notions, and a bare desire;  
 What by small toys we now do comprehend,  
 Our Predecessors only did admire.

2.  
 Now fruitful Reason, arm'd with powerful Art,  
 Uncovers Nature to each knowing eye:  
 Our Author to the World doth here impart  
 What was before esteem'd a mystery.

3.  
 The various motions of that Element,  
 Whose liquid form gives birth to much debate;  
 By demonstration he doth represent,  
 Unfolding th' intricues of that subtil state.

4.  
 The Waters Course, and Sourse, from whence they flow,  
 By him to th' sense so clearly are display'd:  
 Their current Weight, and Measure now we know,  
 'Tis no more secret, but an open Trade.

W. C.

HYDRO-



# Hydrostatical THEOREMS,

Containing some useful Principles in order to that excellent Doctrine, anent  
the wonderful *Weight, Force, and Pressure* of  
the Water in its own Element.

## THEOREM I.

*In all Fluids, besides the first and visible Horizontal surface, there are many more imaginary, yet real.*

Figure 1.



OR the better understanding the following Experiments, it is needful to premit the subsequent Theorems; the first whereof is, that in all Fluid bodies, such as Air, Water, and Mercury, or any other liquid, there is besides the first and visible surface, innumerable more imaginary, under that first, yet real, as may be seen from the following Schematism, which represents a Vessel full of Water, where besides the first surface

A

A B

A B C D, there is a second E F G H, and a third I K L M, and so downward, till you come to the bottom. This holds true, not only in Water, but in Air also, or in any other Fluid body whatsoever. I call the under-surfaces imaginary, not because they are not real; for true and real effects are performed by them; but because they are not actually distinguished amongst themselves, but only by the Intellect.

### THEOREM II.

*In all Fluids, as it is needful to conceive Horizontal Plains, so it is needful to conceive Perpendicular Pillars, cutting these Plains at right Angles.*

Figure 1.

**T**His Proposition is likewise needful for understanding the following Doctrine, anent the Pressure of the Water: for in it, as in all Fluids, though there be not Columes or Pillars actually divided, reaching from the top to the bottom; yet there are innumerable *imaginary*, which do as really produce effects by their pressure, as if they were actually distinguished. These *imaginary* Pillars are represented in the first Schematism, one whereof is A E I N O P Q, the other B F K R T, and so forth.

### THEOREM III.

*There is a twofold Balance; one Natural, another Artificial.*

**B**Y the *Artificial Balance*, I understand that which the Mechanicks call *Libra*, which Merchants commonly use. By the *Natural Balance* (which for distinctions cause

Lfo

I (o nominat) I mean, *u. g.* a *Siphon*, or crooked Pipe, wherein water naturally ascends or descends, as high or low in the one Leg, as in the other, still keeping an evenness, or likeness of weight,

## THEOREM IV.

*Fluid bodies counterpoise one another in the Ballance of Nature, according to their Altitude only.*

**T**His Theorem will appear afterwards most evident, while we pass through the several Experiments, and it is of special use for explicating sundry difficulties that commonly occur in the *Hydrostaticks*. The meaning of it is shortly this: while two Cylinders of Water are in the opposite Scales of the *Natural Ballance*, they do not counterpoise one another according to their thickness: for though the one Pillar of Water be ten times thicker, then the other, and consequently heavier, yet is it not able to press up the other, that's more slender, and so lighter, beyond its own height: and therefore they weigh only according to their *Altitudes*.

## THEOREM V.

*In all Fluids there is a Pressure.*

Figure 1.

**T**His is true not only of the Elements of Air, and Water, while they are out of their own place (as they speak) but while they are in it. For Air and Water, being naturally indued with weight, the second foot cannot

A 2

be



be under the first, unless it sustain it: If this be, it must necessarily be prest with its burden. So this Water being naturally a heavy body, the foot I cannot be under E, unless it sustain it, and be prest with the burden of it; the foot N, being burdened with them both. From this Pressure, which is in Air, ariseth a certain sort of force, and power, which may be called *Bensil*, by vertue whereof, a little quantity of Air, can expand and spread out it self, to a very large quantity, and may by extrinsick force be reduced to that small quantity again. Though this expansive faculty be evident in Air, yet it is scarcely discernable in Water, unless it be in very deep parts, near the bottom, where the Pressure is great. This Pressure is not of the same Degree in all the parts, but is increased and augmented, according to the deepness of the Air, and Water: for the Air upon the tops of Mountains, and high places, is thought to be of a less Pressure, then in Valleys: and Water is of a less Pressure, ten or twelve foot from the top, then twenty or thirty. So is the Water N, under a far less Pressure, then the Water, P or Q.

### THEOREM VI.

*The pressure of Fluids is on every side.*

Figure 1.

**T**He meaning is, that Air and Water presseth not only downward, but upward, not to the right hand only, but to the left also, and every way. So the foot of water K, not only presseth down the foot R, but presseth up the foot F, yea presseth the foot I, and the foot L, with the same weight. And the first imaginary surface, is as much prest

prest up, by the water I K L M, as it is prest down by the water E F G H. Upon this account it is, that when a Sphere, or Glob is suspended in the midle of Water, or Air, all the points of their surfaces are uniformly prest. After this manner, are our bodies prest with the invironing Air, and the man that *dives*, with the ambient and invironing Water.

### THEOREM VII.

*All the parts of a Fluid in the same Horizontal Line,  
are equally prest.*

Figure 1.

**T**He meaning is, that the foot I, is no more prest, then the foot K: neither is the foot L, more burdened, then the foot M. The reason is, because each of these feet, sustains the same weight: for E F G H are all of them, of the same burden: therefore all the parts of a Fluid in the same Horizontal surface, are prest most equally. This holds true in Air, and Mercury, or in any other Liquid also.

### THEOREM VIII.

*The Pressure of Fluids seem to be according to  
Arithmetical Progression.*

Figure 1.

**T**He meaning is, that if the first foot of Water, have one Degree of Pressure in it, the second must have only two, and the third must have only three, and so forth, which

which appears from the Schematism : for the first foot E, having one Degree of weight, and the second foot I, having of its self as much, and sustaining E, it must have two Degrees, and no more. So the foot N, sustaining two Degrees of Pressure from I and E, must have the weight only of three Degrees, O of four, P of five. It's evident also from Experience, for while by the Pressure of Water, Mercury is suspended in a glass tub, we find, that as the first fourteen inches of Water, sustains one inch of Mercury, so the second fourteen inches sustains but two, and the third, but three. But if the Pressure were according to *Geometrical progression*, the third foot of Water ought to sustain four inches of Mercury, the fourth, eight; the fifth, sixteen, &c. which is contrary to Experience.

## THEOREM IX.

*In all Fluids there is a twofold weight, one Sensible,  
the other Insensible.*

**T**He first is common to all heavy bodies, which we find in Water, while we lift a Vessel full of it from the ground. The *Insensible weight* of Water, and Air, or of any other Fluid, can scarcely be discerned by the senses, though it be as real, as the former, because the Pressure is uniform. By vertue of the second, bodies naturally lighter than Water, are driven from the bottom to the top, as *Cork*. So, a man falling into a deep Water, goes presently to the bottom, and instantly comes up again. Here is a natural effect, which cannot want a natural cause; and this can be nothing else, but the Pressure of the Water, by vertue whereof he comes up, and yet he finds nothing

thing driving him up, or pulling him up. Therefore, there is in all Fluid bodies, an *Insensible* weight, as there is one *Sensible*; seing the man that (perhaps) weighs seventeen Stone, is driven up fifteen or sixteen fathom by it. And it must be very considerable, and exceed the weight of the man, seing it is able to overcome such a weight. So are vapours and smoke driven upward by the *Insensible* weight of the Air, and by that same weight, do the Clouds swim above us.

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### THEOREM X.

*The Insensible weight of Fluids, is only found by sense, when the Pressure is not uniform.*

**F**OR understanding of this Proposition, I must suppose somethings that are possible, but not practicable. Put the case then, while a man opens his hand, the Air below were removed, he would scarce be able to sustain the weight of the Air, that rests upon the Palm above: or if the Air above were annihilated, he would not be able to bear down the weight that presseth upward. Or, while a *Diver* is in the bottom of the Sea, if it were possible to free any one part of his body from the Pressure of the Water, suppose his right arm, I doubt not, but the blood would spring out in abundance from his finger-ends: for the arm being free, and the other parts extreamly prest, the blood of necessity must be driven from the shoulder downward, with force, which cannot be without considerable pain. It is evident also, from the application of the *Cuppin-glass*, which being duely applied to a mans skin, causeth the Air to press unequally, the parts with-  
out,

out, being more prest, than the parts within, in which case the unequal Pressure causeth the pain, and so is found by sense.

### THEOREM XI.

*A Cylinder of Water, or of any other Fluid body, loseth of its weight, according to its reclinacion from a Perpendicular position, towards an Horizontal or levell situation.*

FOR understanding of this, consider that while a Pipe full of Water stands perpendicular, the lowest foot sustains the whole weight of the Water above it: but no sooner you begin to recline the Pipe from that Position, but assoon the Pressure upon the lowest foot grows less; So that if the lowest foot, in a perpendicular position, sustained the burden of ten feet, it cannot sustain above five or six, when it is half reclined. A certain evidence whereof is this, the more a Cylinder of Water is reclined towards the Horizon, or Level, it takes the shorter Cylinder of Water to counterpoise it, as is evident in *Siphons*. For, though the one Leg, be sixteen inches long, and the other but six; yet a Cylinder of Water six inches long, will counterpoise a Cylinder of sixteen. But this cannot be, unless an alteration be made in the Pressure. For, how is it possible, that a Cylinder of Water can sometimes be in *aquilíbrio* with a lesser, and sometimes with a greater weight, unless the Weight, and Pressure of it, be sometimes more, and sometimes less? When I say a Cylinder of Water loseth of its weight by reclinacion, it is to be understood only of the *Insensible Weight*: for the



the *Sensible Weight* is unchangeable, being it is always a Pillar of so many inches, or feet. Now the true reason, why the Pressure upon the lowest foot grows less, is this; the more the Pipe is reclined, the more weight of the Cylinder rests upon the sides of the Pipe within; by which means, the lowest foot is eased of the burthen, and is altogether eased, when once the Pipe lyes Horizontal,

## THEOREM XII.

*All motion in Fluids; is from the unequal Pressure of the Horizontal surface.*

Figure 1.

FOR understanding this, I must distinguish a twofold motion in Fluids; one *common*, another *proper*, by vertue of the first, they incline, as all other heavy bodies, to be at the center of the Earth. It is evident in the motion of Rivers, which descend from the higher places to the valleys, even by vertue of that tendency they have to be at the center. By vertue of the second, they incline to move every way; not only downward, but upward, hither and thither. This sort of motion is peculiar, and proper only to Fluids; and it is that which is spoken of in this Theorem. I say then, that all motion in Fluids, is from the unequal Pressure of the Horizontal surface. For put the case A, were more prest then B, e.g. with a stone, then surely as the part A descends, the other part B will ascend; and so will C and D rise higher too. Suppose next, the part A were freed of the Pressure of the Air, then surely in the same instant of time, would the part A ascend, and the parts B C D descend. As this Proposition is true in order

to the first and visible surface  $A B C D$ , so it is true in order to the imaginary surface  $I K L M$ ; for put the case the space  $I$ , were filled with a body naturally heavier then Water, as lead or stone, then behoved that part of the surface to yeeld, it being more prest, then the part of the same surface  $K$ . Or if the space  $K$  were filled with a body naturally lighter then water, as Cork, then ought the water  $R$  to ascend, it being less prest, then the water  $N$  or  $S$ .

### THEOREM XIII.

*A body naturally heavier then Water, descends; and a body naturally lighter, ascends.*

Figure 1.

**F**OR understanding of this, let us suppose the quadrat space  $E$ , to be filled with a piece of Lead or Iron. I say then it must go down to  $I$ ; and the reason is, because the quadrat foot of Water  $I$ , is more pressed then the quadrat foot of Water  $K$ . To illustrate this, let us suppose that each quadrat foot of this Water weighs a pound, and that the heavy body existing in  $E$ , weighs two pound. If this be, the foot of Water  $I$ , must yeeld, seeing it is more prest then  $K$ : upon the same account must the Water  $N$  yeeld, and give way to the Stone, seeing it is more prest then  $R$ . For according to the twelfth Theorem, *There cannot be unequal Pressure upon a surface, unless motion follow.*

For understanding the second part, let us suppose the space  $R$ , to be filled with a piece of Cork, that is specifically or naturally lighter then Water. I say then, it must ascend to the top  $B$ ; and the reason is, becaute the quadrat foot of Water  $K$ , is more prest upward, then the quadrat

quadrat foot of Water I, or L is: But this cannot be in Fluid bodies, unless motion follow thereupon. I say, it is more prest up, because R being lighter then N, or S, it must press with greater force upon K, then S can do upon L, or N upon I. It is still to be remembred, *That Fluids presseth with as much strength upward, as downward*, according to the sixth Theorem; and that an Horizontal surface doth as really suffer unequal Pressure from below, as from above.

## THEOREM XIV.

*Bodies naturally lighter then Water, swim upon the surface and top.*

Figure. x.

**T**He reason of this Proposition must be taken from the nature of an *equipondium*, or equal weight. For without doubt, there is a counter-balance between the Pressure of the Water, and the weight of the body that swims. To make this probable, let us suppose there were a piece of Timber in form of a Cube, six inches thick every way, without weight. In this case, the under-surface of that four-squard body, being applied to the surface of the Water A, would ly clos upon it, as one plain Table lyes upon the face of another, without any pressure: and it being void of weight, the part of the surface A, would be no more burdened, then the next part B adjacent, whence no motion would follow. Here is no *equipondium*, or counter-balance.

Secondly, let us suppose the said body to acquire two ounces of weight, then it follows, that it must subside, and sink two inches below the surface A B C D; and that

so far, till it come by vertue of its new acquired weight, to a counter-balance with the Pressure of the Water. Which Pressure is nothing else, but as much force or weight, as is equivalent to the weight of Water, that is thrust out of its own place, by the subsiding and sinking of that body, two inches.

Thirdly, let us suppose the same body to acquire other two ounces of weight, then must it subside other two inches. Lastly, let us suppose that it acquires six ounces of weight, then it follows that the whole body sinks, so far, I mean, till its upmost surface be in an *Horizontal line* with the surface of the Water *A B C D*. Here it swims also, because the weight of it becomes just the weight of so much Water, as it hath put out of its own place. I say, it must swim, because if the Water *I*, was able to sustain the Water *E*, which is put from its own place, surely it must be able to sustain that body also, that did thrust it from its own place, seeing both are of the same weight, namely six ounces. In this case, the body immersed, and the water wherein it is drowned, become of the same weight *specifically*, seeing bulk for bulk is of the same weight. To make this body *specifically*, or naturally heavier then Water, and consequently to sink to the bottom, nothing is required, but to suppose that it acquires one ounce more of weight; which done, it presently goes down, *I*, being more burdened then *K*. Note by the way, a twofold weight in heavy bodies; one *individual*, the other *specific*, and that two bodies agreeing in *individual* weight, may differ in *specific* weight. So a pound of Lead, and a pound of Cork, agree *individually*, because they are both 16 ounces: but they differ *specifically*, because the one is naturally heavier then the other.

THEOREM XV.

*No Body that floats above Water, even though its upper surface be level with the surface of the Water, can ever be made to swim between the top and the bottom.*

Figure 1.

FOR clearing this Proposition, let us suppose F to be a four-square piece of Timber, of the same *specifick* and natural weight with Water, and consequently its upper surface to be level with the surface of the Water ABCD. I say then, if it be prest down to R, it shall arise thence, and never rest till it be where it was, namely in F. The reason seems to be this, because the four-squar'd body of Water R, is really heavier, then the four-squar'd piece of Timber F. If this be true, it follows of necessity, that it must ascend: for if the Timber existing in R, be lighter then the Water R, the Water T must be less prest, then the Water O, or the Water V; whence (according to the twelfth Theorem) *motion must follow*. Again, if the Timber R, existing in the Water R, be lighter then the same Water is, then must the Water K, be more prest-up then the Water I, or L; whence yet, according to the same Theorem, *motion must follow*. If it be said, that the Timber F, is of the same weight with the Water R; because, it being equal in weight with the Water F; which it hath thrust out of its own place, it must also be equal in weight to the Water R, seeing F and R being of the same dimensions, are of the same weight. There is no way to answer this difficulty, unless I say the four-squar'd body of water R, is really and truly heavier then the four-squar'd body of Water F. The reason



reason seems to be, because the Water R, is under a greater Pressure, then the Water F; and by vertue of this greater Pressure, there are really *more parts* of Water in it, then in F; therefore it must be heavier. Even as there are far *more parts* of Air, in one cubick foot near the Earth, then in six or seven near the Atmosphere. Hence it is, that a pint of Water taken from the bottom of the Sea, forty fathom deep, will be heavier, I mean in a ballance, then a pint taken from the surface. Take notice, that when the vessel is once full at the bottom, the orifice must be closely stopped, till it come to the top: otherwise the parts that are compressed at the bottom, namely by the weight of the superiour parts, relaxes themselves, before they come to the top.

### THEOREM XVI.

*It is not impossible for a body to be suspended between the surface and the bottom.*

Figure 1.

FOR understanding this, suppose F to be a four-square piece of Timber, which though it will not rest but at the surface, A B C D, yet may be made to go down of its own accord, and rest at T, namely, by making it so much heavier, as the Water T is heavier then the Water F. To know this difference, which is not very practicable, the Cube of Water T, must be brought from its own place, under the same degree of Pressure it hath, and put into the Scale of a Ballance, and weighed with the Cube of Water F, put into the other Scale. Now if the Water T, be half an ounce heavier, then the Water F, then to make the Timber F hang in T, it must be made half an ounce heavier. There seems to be reason for it also; for if a  
Cube

Cube of Timber resting in the space T, be just the weight of the Water T, the *imaginary* surface O T V, is no more prest, then if T were Water, and so it cannot go downward: neither can it go upward, seeing the under part of the Water R, is no more prest up by the Timber T, then if the space T were filled with Water. If it be said, according to this reasoning, a Stone may be suspended in a deep Water, between the top and the bottom, which is absurd. I answer, such a thing may happen in a very deep Water: For put the case a Cube of Lead twelve inches every way, were to go down twelve thousand fathom, it is probable, it would be suspended before it came to the ground. For coming to an *imaginary* surface far down, where the Pressure is great, a Cube of Water twelve inches thick there, may be as heavy (even *specifically*) as the Cube of Lead is, though the Lead be ten-times heavier *specifically*, then any foot of Water at the top. If Water suffer compression of parts, by the superiour burden; it is more then probable, that the second foot of Water burdened with the first, hath more parts in it, then are in the first, and the third more, then in the second, and so forth; and consequently, that the second is heavier, then the first, and the third heavier, then the second. Now, if this be, why may not that foot of Water, that hath sixty thousand foot above it, by vertue of this burden, be so compressed, that in it may be as many parts, as may counter-balance a Cube of Lead twelve inches every way: If then, that *imaginary* surface, that is sixty thousand foot deep, be able to sustain the said foot of Water, which perhaps weighs twenty pound, why may it not likewise sustain the Lead, that is both of the same dimensions with it, and weight?

Hence

Hence it is, that the Clouds do swim in the Air, by virtue of a counter-balance: And we see, which confirms this Doctrine, that the thinnest and lightest are alwayes farthest up; and the thickest and blackest, are alwayes farthest down.

### THEOREM XVII.

*The lower the parts of a Fluid are, they are the heavier, though all of them be of equal quantity and dimensions.*

Figure 1.

**T**His follows from the former, which may appear a Paradox, yet it seems to be true: for though the Water Q at the bottom, be of the same dimensions with the Water E at the top, yet it is really heavier, which happens (as I said) from the superiour Pressure. It is clear also from this, namely the Cube of Timber E, which swims upon the surface, being thrust down to Q, comes up to the top again, which could not be, unless the Water Q, were heavier then the Water E. I suppose the Water E, and the Timber E, to be exactly of the same specific weight, and consequently the surface of the Timber, to ly Horizontal with B C D. Now the reason, why the Timber ascends from Q to E, is no other then this, namely that the one Water is heavier then the other; for the under part of the Water P, being more prest up with the Timber existing in Q, then with the Water Q it self, it must yeeld and give way to the ascent: for if the Cube of Timber existing in Q, were as heavy as the Water Q it self, it would no more prest upon P, or endeavour to be up, then the Water Q does.

T H E O -

## T H E O R E M X V I I I.

*A heavy body weighs less in Water, then in Air.*

Figure 1.

**T**His is easily proven from experience ; for after you have weighed a stone in the Air , and finds it two pound, and an half, take it, and suspend it by a threed knit to the scale of a ballance, and let it down into the Water, and you shall find it half a pound lighter. The question then is, why doth it lose half a pound of its weight ? I answer, the stone becomes half a pound lighter, because the surface of Water on which it rests, sustains half a pound of it: For put the case a stone were resting in R, that weighed two pound and an half in the Air , it behoved to weigh but two pound in this Water ; because the Water T sustains half a pound of it. For if this Water T be able to sustain the Water R, that weighs half a pound, it must be also able to sustain half a pound of the stone, seing half a pound of stone is no heavier, then half a pound of Water. Note, that when a heavy body is weighed in Water, it becomes so much lighter exactly, as is the weight of the Water it thrusts out of its own place.

## T H E O R E M X I X.

*A heavy body weighs less nigh the bottom of the Water, then nigh the top thereof.*

Figure 1.

**F**Or clearing this proposition, I must suppose from the 17. Theorem, that the lower the parts of Water  
C
be,

be, they are the heavier, though all of them be of equal dimensions. If then the lowest foot  $Q$  be heavier, that is, have more parts in it, then the foot  $N$ , it of necessity follows, that a stone suspended in  $Q$ , must be lighter then while it is suspended in  $N$  or  $I$ . Because, if a stone be lighter in Water then in Air, as is said, even by as much, as is the weight of the bulk of Water, that the bulk of the stone expells, then surely it must be lighter in the one, then in the other place; because suspended in  $Q$ , it expells more parts of Water, then while it is suspended in  $N$  or  $I$ . For example, let us suppose the Water  $N$ , to weigh eight ounces, and the Water  $Q$  to weigh nine, then must the stone suspended in  $Q$ , weigh less by an ounce, then suspended in  $N$ , seeing as much is deduced from the weight of the stone, as is the weight of the Water it expells: but so it is, that it thrusts nine ounces of Water out of its own place in  $Q$ , and but eight in  $N$  or  $I$ ; therefore it must be one ounce lighter in the one place, then in the other. This may be tried, with a nice, and accurat ballance, which will bring us to the knowledge of this, namely how much the foot of Water  $Q$  is heavier, then the Water  $N$  or  $O$ .

### THEOREM XX.

*One part of a Fluid, cannot be under compression, unless all the parts next adjacent, be under the same degree of Pressure.*

Figure 1.

**T**His proposition may be proven by many instances: for when the Air of a *Wind-gun*, is reduced to less quantity by the Rammer, all the parts are most exactly of the same *Benfil*. So is it in a Bladder full of wind. It's true,



true, not only in order to this artificial Pressure, but in order to the natural Pressure, and *Bensil* of the Air likewise. For the Air within a parlour, hath all its parts, under the same degree of natural compression: so is it with the parts of the Air, that are without, and immediatly under the weight of the *Atmosphere*. Its evident also in the parts of Water: for the foot of Water R, cannot be under Pressure, unless the Water S, and N, be under the same degree of it. Though this be true of Fluids, while all the parts lye in the same Horizontal surface, yet to speak strictly, it will not hold true of the parts situated under divers surfaces; for without question, the foot of VWater T, must be under four degrees of Pressure, if the VWater R, be under three. And if the Air in the lowest story of a building, be under six degrees of *Bensil*, the Air in the highest story must be under five. If a man would distinguish *Metaphysically*, and subtilly, he will find a difference of this kind, not only between the first, and second fathom of Air, nearest to the Earth, but between the first, and second foot, yea, between the first and second inch, and less, much more in Water, as to sense. However it be, yet the Theorem holds true; for we find no difference sensible, between the compression of Air in this room; and the compression of Air in the next room above it, no not with the *Baroscope*, or *Torricellian Experiment*, that discerns such differences accurately. I judge it likewise to be true, in order to the next adjacent parts of Fluids of different kinds, for while a surface of Mercury, is burdened with a Pillar of Water, or a surface of Water, with a Pillar of Air, whatever degree of weight and Pressure, is in the lowest parts of these Pillars, the same is communicated entirely, to the surfaces, that sustains them. So then, there is as much

force and power, in the surface of any Water, as there is Weight and Pressure, in the lowest foot of any Pillar of Air, that rests upon it: otherwise, the surface of Water would never be able to support the said Pillar: for a surface of six degrees of force, can never be able to sustain a Pillar of Air, of eight, or ten degrees of weight.

### THEOREM XXI.

*The Pressure of Fluids, may be as much in the least part, as in the whole.*

Figure 1.

**T**His Theorem may seem hard, yet it can be made manifest, by many instances: for albeit the quantity of Air, that fills a Parlour, be little in respect of the whole Element, yet surely, there is as much Pressure in it, as in the whole; because Experience shews, that the *Mercurial Cylinder* in the *Baroscope*, will be as well sustained in a Chamber, as without, and under the whole *Atmosphere* directly; which could not be, unless the small portion of Air, that's in this Parlour, had as much Pressure in it, as in the whole Element. Besides this, it will be found in a far less quantity: for though the *Baroscope* were inclosed, and imprisoned so close, within a small Vessel, that the Air within, could have no communion with the Air without, yet the Pressure of that very small quantity, will sustain 29. inches of Mercury, and this will come to pass, even though the whole Element of Air were annihilated. This Proposition is likewise evident in order to the Pressure of the Water: for put the case, the *Baroscope*, whose *Mercurial Cylinder* is 29. inches, by the Pressure of the Air;

Air, were sent down to the bottom of a Sea 34. foot deep, within a Vessel, as a Hogs-head, and there exactly inclosed, that the VVater within, could have no commerce with the VVater without, yet as well, after this shutting up, as before, other 29. inches would be sustained, by the Pressure of this imprisoned VVater, which proves evidently, that there is as much Pressure in one Hogs-head full of VVater, at the bottom of the Sea, as in the whole Element of VVater, above, or about: for an Element of VVater never so spacious, if it exceed not 34. foot in deepness, can sustain no more Mercury, then 29. inches by its Pressure. Yea, though the Vessel with the *Baroscope*, and imprisoned VVater in it, were brought above to the free Air, yet will the VVater retain the same Pressure, and will *de facto* sustain 29. inches of Mercury, provided the Vessel be kept close. It is therefore evident, that as much Pressure may be in one small quantity of VVater, as in the whole Element, or Ocean. 'Tis to be observed, that this Theorem is to be understood chiefly of the lower parts of Fluids; seing there cannot be so much Pressure in the VVater P, as in the VVater Q; for in effect, there is as much Pressure in the VVater Q, as is in the whole VVater above it, or about it. From this Theorem, we see evidently, that the Pressure, and *Bensil* of a Fluid, is not to be measured, according to its bulk, and quantity, seing there is as much *Bensil* in one foot, nay, in one inch of Air, as is in the whole Element, and as strong a Pressure in one foot of VVater, or less, as there is in the whole Ocean: therefore the greatest quantity of Air, hath not alwayes the greatest *Bensil*, neither the greatest quantity of VVater, the greatest Pressure. But this will appear more evident afterwards.

THEO-

## THEOREM XXII.

*The Pressure, and Bensil of a Fluid, is a thing, really distinct from the natural weight of a Fluid.*

Figure 1.

*Consl.* **T**HIS may be easily conceived; for as in solid bodies, the *Bensil*, and *natural weight*, are two distinct things, so is it in Air, and Water, or in any other Fluid. The weight of a *Bow*, is one thing, and the *natural weight* of it, is another. The weight of the Spring of a *Watch*, and the *Bensil* of it, are two distinct things. The weight (perhaps) will not exceed two ounces: but the *Bensil* (may be) will be equivalent to two pound. Though these may illustrate, yet they do not convince: therefore I shall adduce a reason, and it's this. The *natural weight* of a Fluid is less, or more, as the quantity is less or more; but it is not so with the Pressure, because there may be as much Pressure in a small quantity, as in a great, as is evident from the last Theorem, therefore they may be different. The first part of the Argument is manifest, because there is more weight in a gallon of Water, than in a pint. A second reason is, because a Fluid may lose of its pressure, without losing of its weight. This is evident from the Schematism, for if you take away the four foot of Water EFGH, and consequently make the four Pillars shorter, the foot of Water Q becomes of less Pressure, but not of less Weight, seeing the quantity still remains the same: at least, the loss of weight is not comparable, to the loss of Pressure. I say, it becomes of less Pressure, because there is a less burden above it. Thirdly, the Pressure

sure and *Bensil* may be intended, and made stronger, without any alteration in the weight: so is the *Bensil* of Air, within a Bladder, made stronger by heat, without any alteration, in the weight of it. Likewise, the Pressure of the foot of Water Q, may be made stronger, by making these four pillars higher, without any alteration, at least considerable, in the weight; for it still remains a foot of water, whatever be the height of the pillars above it. Lastly, the weight of a Fluid is *essential* to it, but the Pressure is only *accidental*; because it is only generated, and begotten in the inferiour parts, by the weight of the superiour, which weight may be taken away.

### THEOREM XXIII.

*Though the Bensil of a Fluid, be not the same thing formally with the weight, yet are they the same effectively.*

**T**His proposition is true in order to many other things, besides Fluids: for we see that the *Sun*, and *Fire*, are *formally* different, yet they may be the same *effectively*; because the same effects, that are done by the heat of the *Sun*, may be done by the heat of the *Fire*. So the same effects, that are produced by the *weight* of a Fluid, may be done by the Pressure, and *Bensil* of it. Thus, the Mercurial Cylinder in the *Torricellian Experiment*, may be either sustained by the *Bensil* of the Air, or the *weight* of it. By the *Bensil*, as when no more Air, is admitted to rest upon the stagnant Mercury, then three or four inches, the rest being secluded, by stopping the orifice of the Vessel. By the *weight* of it, as when an intire Pillar of Air, from the top of the Atmosphere, rests upon the face of the stagnant Quick-

Quicksilver. It is also evident in a *Clock*, which may be made to move, either by a weight of Lead, or by the force, and power of a *Steel Spring*.

### THEOREM XXIV.

*The surfaces of Waters, are able to sustain any weight whatsoever, provided that weight press equally, and uniformly.*

Figure 1.

**T**His is evident, because the imaginary surface of **V**Water **O T V X**, doth really support the whole sixteen Cubes of **V**Water above it, yea, though they were sixteen thousand. And the reason is, because they press most equally, and uniformly. **V**What I affirm of the imaginary surface, the same I affirm, of the first and visible. For let a plain body of lead, never so heavy, be laid upon the top of the **V**Water **A B C D**, yet will it support it, and keep it from sinking, provided it press uniformly all the parts of that surface. It is clear also, from the subsequent Theorem.

### THEOREM XXV.

*The surfaces of all Waters whatsoever, support as much weight from the Air, as if they had the weight of thirty four foot of Water above them, or twenty nine inches of Quick-silver pressing them.*

**T**His Proposition is evident from this, that the Pressure of the Air, is able to raise above the surface of any Water, a Pillar of Water thirty four foot high. For,  
put



put the case there were a *Pump* forty foot high, erected among stagnant Water, and a *Sucker* in it, for extracting the internal Air, a man will find, that the Water will climb up in it four and thirty foot, which *Phænomenon* could never happen, unless the surface of the stagnant Water, among which the end of the *Pump* is drowned, were as much press'd with the Air, as if it had a Burden of Water upon it thirty four foot high. The second part is also evident, because if a man drown the end of a long Pipe, in a Vessel with stagnant Quick-silver, and remove the Air that's within the Pipe by a *Sucker*, or more easily by the help of the *Air-pump*, he will find the Liquor to rise twenty nine inches, above the surface below, which thing could never come to pass, unless the Pressure of the Air, upon the surfaces of all Bodies, were equivalent to the Pressure and weight of twenty nine inches of Quick-silver.

**THEOREM XXVI.**

*All Fluid Bodies have a Sphere of Activity, to which they are able to press up themselves, or another Fluid, and no further, which is less or more, according to the altitude of that pressing Fluid.*

Figure 2.

**F**OR understanding this Proposition, let us imagine **G H C D** to be a Vessel, in whose bottom, there are five inches of Mercury **E F C D**. Next, that above the stagnant Mercury, there are thirty four foot of Water resting, namely **A B E F**. Lastly, that upon the surface of the said Water, there is resting the Element of Air **G H A B**, whose top **G H**, I reckon to be about

D

six

six thousand fathom above A B. Besides these, let us imagine, that there are here three Pipes, open at both ends, the first whereof C A G, having it's lower orifice C, drowned among the stagnant Mercury E F C D, goeth so high, that then pper orifice goeth above the top of the Air G H. The second, whose lower orifice I, is only drowned among the Water A B E F, reaches to the top of the Air likewise. The third, whose open end K, is above the surface of the VVater A N B, and hanging in the open Air, goeth likewise above the Atmosphere. These things being supposed, we see that no Fluid can, by it's own proper weight, press any part of it self, higher then it's own surface, seing the stagnant Mercury E F C D, cannot press it self within the Pipe C G, higher then E. Neither can the VVater A B E F, press it self higher within the Pipe I L, then the point N. Lastly, neither can the Air G H A B, press it self within the Pipe K M, higher then M. But when one Fluid presseth upon another, as the VVater A B E F, upon the Mercury E F C D, then doth the said Mercury ascend higher than it's own surface, namely from E to O, which point is the highest, to which the thirty four foot of VVater A B E F, can raise the Mercury, which altitude, is twenty nine inches above the surface. E I F. But if a second Fluid be super-added, as the whole Air G H A B, then must the Mercury, according to that new Pressure, rise by proportion; so rises the Mercury from O to P, other twenty nine inches. By this same additional weight of Air, the Water rises thirty four foot in the Pipe I L, namely from N to R. Now, I say, the outmost and highest point, to which the Element of Air G H A B can raise the Mercury, is from O to P; for by the Pressure of the Wa-

ter A B E F, it rises from E to O. And the highest point, to which the said Air can raise the VVater, is from N to R. The reasons of these determinate altitudes, must be sought for, from the altitudes of the incumbering and pressing Fluids: for as these are less or more, so is the altitude of the Mercury, and of the VVater within the Pipes more or less. The hight therefore of the Mercury E O, is twenty nine inches, because the deepness of the pressing water A B E F is thirty four foot. And the hight of the VVater N R, is thirty four foot, because the hight of the Air G H, above A B, is six thousand fathom, or thereabout. And for the same reason, is the Mercury O P twenty nine inches.

### THEOREM XXVII.

*A lighter Fluid, is able to press with as great burden, as a heavier.*

Figure 2.

**T**His Proposition is true, not only of VVater in respect of Mercury, but of Air in respect of them both: for albeit Air be a thousand times lighter then VVater, yet may it have as great a Pressure with it, as VVater; as is evident from this second Schematism, where by the Pressure of the outward Air G H A B, twenty nine inches of Mercury O P are supported, as well as the twenty nine inches E O, by the Pressure of the VVater A B E F. So doth the same Air, sustain the thirty four foot of VVater N R, which are really as heavy, as the twenty nine inches of Mercury O P. Now, if the weight of the Atmosphere, be equivalent to the

weight of thirty four foot of Water, or of twenty nine inches of Mercury, is no wonder to see Water press with as great weight as Mercury, which is likewise clear from this same Figure, where by the Pressure of the Water  $A B E F$ , twenty nine inches of Mercury  $E O$  are suspended, as truly as the Mercury  $G B$ , within the lower end of the Pipe, is supported by the outward invading Mercury. The reasons of these *Phenomena*, are taken from the altitudes of the pressing Fluids: for though a Body were never so light, yet multiplication of parts makes multiplication of weight; which multiplication of parts in Fluids, must be according to altitude: for multiplication of parts according to thickness and breadth will not do it. Observe here, that if as much Air, as fills the Tub between  $N$  and  $L$ , were put into the scale of a Ballance, it would exactly counterpoise the thirty four foot of Water  $N R$ , poured into the other scale. Item, that as much Water as will fill the Tub between  $E$  and  $A$ , is just the weight of the Mercury  $E O$ . Lastly, that as much Air as will fill the Pipe, between  $O$  and  $G$ , is just the weight of the Mercury  $O P$ .

### THEOREM XXVIII.

*The Pressure of Fluids, doth not diminish, while you subtract from their thickness, but only, when you subtract from their altitude.*

Figure 1.

**F**OR understanding this, let us look upon the first Schematism, where there are four Pillars of Water. Now I say, though you cut off the three Columns of Water, upon the right side, yet there shall remain as much Pressure,

sure, in the quadrat foot of VWater Q, as was, while these were intire. But if you cut off from the top, the VWater EFGH, then presently an alteration follows, not only in the lowest parts, nigh to the bottom, but through all the intermediat parts: for not only the VWater Q loseth a degree of its Pressure, but the VVaters P and O suffer the same loss. This Theorem holds true likewise in order to the Element of Air. For if by *Divine Providence*, the Air should become less in Altitude, than it is; then surely, the *Bensl* of the ambient Air, that we breath in and out, should be by proportion weakned also. And contrariwise, if the Altitude became more, then stronger should the *Bensl* be here, with us, in the lowest parts: both which would be hurtful to creatures, that live by breathing. For if the Altitude of the Air, were far more then it is, our bodies would be under a far greater Pressure, which surely would be very hurtful. And upon the other hand, if the Altitude of the Air, were far less then it is, we should be at a greater loss, for then, by reason of the weak *Bensl*, we would breath indeed, but with great difficulty.

**THEOREM XXIX.**

*A thicker Pillar of a Fluid, is not able to press up a slenderer, unless there be an unequal Pressure.*

Figure 3.

**F**OR understanding this, let us suppose this third Schematism to represent a vessel with VWater in it, as high as A B, among which is thrust down to the bottom, the Pipe G H, open at both ends. I say then, the two thicker Pillars

Pillars of Air E A, and F B, pressing upon the surface of the V Water A B, are not able to press up the Water H I, or the slender Pillar of Air I G within the Pipe, the one higher then I, the other higher then G. If it be said, they are heavier, because they are thicker. I answer, they are truly heavier, for the Pillar of Air F B apart, will be thrice as heavy, as the slender Pillar of Air I G. But, if you reckon the Pillar of Air E A, upon the left hand, both together, will be six times heavier, then the Air I G: yet are they not able, either severally, or conjunctly, to press up the Water H I, higher then I, or the Air I G, higher then G. For solving this difficulty, I must say conform to the fourth Theorem, that Fluid Bodies, counterpoiseth one another, not according to their *thickness*, and *breadth*, but according to their *altitude* only: therefore, seing the slender Pillar of Air I G, is as high, as either F B, or E A, it cannot be prest up by them. For by vertue of this equal hight, all the three press equally and uniformly, upon the surface of Water A B; and therefore according to the twelfth Theorem, there can be no motion. But if so be, the Pillar F B, were higher then the Pillar I G, then surely would the Water H I, be prest up; for in such a case, there is an unequal Pressure. Or if the Pillar I G, were higher then the Pillar F B, then surely would the Water I H be prest down, there being again an unequal Pressure: the Water within the Pipe, being more burdened then the Water about the Pipe. In a word, there's no more difficulty here, then if the Pipe were taken away: in which case, there would be but one Pillar of Air, resting upon the surface of Water A B. If it be said, the Pipe being thrust down, makes of one Pillar, three distinct ones, and conse-



consequently a formal counter-balance, or mutual sustentation. Be it so, yet because all these press uniformly, there can be no motion.

THEOREM XXX.

*Fluids press not only according to perpendicular Lines, but according to crooked Lines.*

Figure 4.

For proving this Proposition, let us suppose  $ABCD$ , to be a large Vessel full of  $VV$ ater, as high as  $ANB$ , and a little Vessel lying within it, near to the bottom, close above at  $M$ , but with an open orifice downward, as  $G$ , and having other two passages going in to it, upon the right, and left side, as  $EO$ , and  $FP$ . Now, I say, the Pressure of this  $VV$ ater, is not only from  $N$  to  $M$ , in a *Straight* line downwards, but from  $E$  to  $O$ , and from  $F$  to  $P$ , by crooked lines. Nay, put the case this Vessel had no passage in to it, but by a *Labyrinth*, or entry full of intricate windings, yet the Pressure will be communicated, thorow all these, even to the middle of it: and which is more, the  $VV$ ater  $H$  or  $I$ , within the Vessel, would be under the same degree of Pressure, with the  $VV$ ater  $E$  or  $L$ , without, or with the  $VV$ ater  $K$  or  $F$ . And which is strange, let us suppose both the entries  $E$  and  $F$  stopped, and nothing remaining open, but the hole  $G$ , which I judge no wider, then may admit the hair of ones head, yet thorow that smal hole, shall the Pressure be communicated, to the parts of the Water within, in as high a degree, as if the upper part of the Vessel  $EML$ , were cut off, to let the Pressure come down directly. What is true

in

Fig. 1

Page

A	B	C	D
E	F	G	H
I	K	L	M
N	R	S	Y
O	T	V	X
P			
Q			

Fig. 2

Page

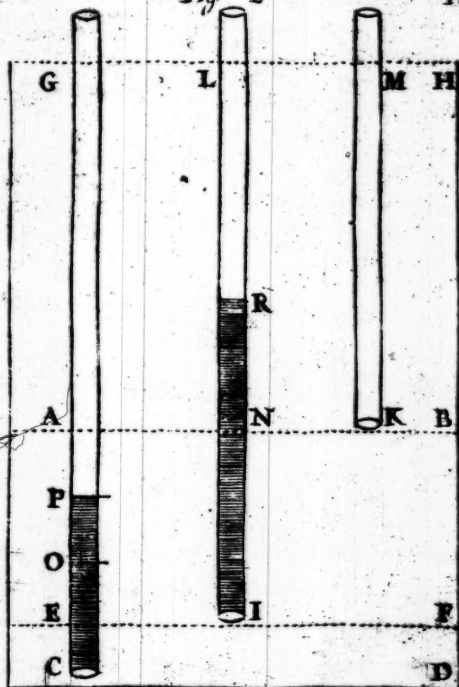


Fig 3

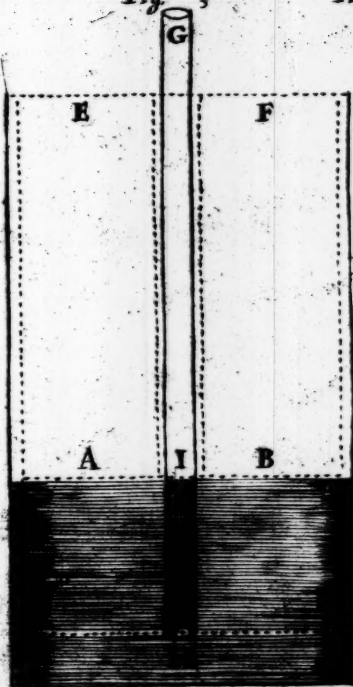
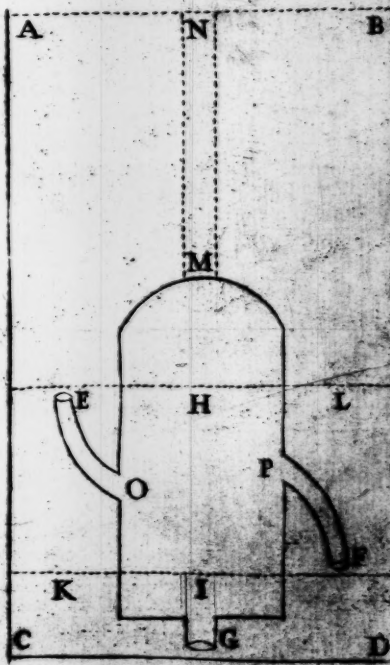


Fig 4



in order to Water, the same is true in order to Air, or Mercury, or any other Fluid. For, though a house were built never so close, without door, or window, yet if there remain but one small hole in it, the Pressure of the whole Atmosphere, shall be transmitted thorow that entrie, and shall reduce the Air within the house, to as high a degree of *Bensil*, as the Air without.

### THEOREM XXXI.

*The Pressure, and Bensil of a Fluid, that's in the Lowest foot, is equivalent to the weight of the whole Pillar above.*

Figure 5.

**F**OR understanding this Proposition, let us suppose *E F* to be the lowest foot of a Pillar of Air, cut off from the rest, and inclosed in the Vessel *E F*, six inches in Diameter, or wideness, and twelve inches high. Now I say, the *Bensil* and Pressure, that's in that one foot of Air, is exactly of as great force and power, as is the weight of the whole Pillar of Air, from which it was cut off. Let *A B* be that Pillar of Air, which I suppose is six inches thick, and six thousand fathom high. Take it, and weigh it in a Balance; and say it weighs 500 pound, yet the Pressure, and *Bensil*, that's in the Air *E F*, is of as much force; and if the one be of strength by its weight, to move, *v. g.* a great Clock, the other by its *Bensil*, will be of as much. This proposition is true also in order to Water. For put the case *E F*, were the lowest of 34 foot of Water: in it will be found as much Pressure, and force, as will be equivalent to the weight of the whole thirty three foot, from which

it was cut off. But here occurreth a difficulty, for if the Pressure, and *Bensil* of the foot of Air E F, be equivalent to the weight of the whole Pillar of Air A B, which weighs 500 pound, then must the slender Pillar of Air C D, that's but two inches in diameter, be as heavy weighed in a ballance, as the thicker Pillar A B, which is absurd. I prove the connexion of the two parts of the Argument thus: as the *Bensil* of the Air G H, is to the *Bensil* of the Air E F, so is the weight of the Pillar C D, to the weight of the Pillar A B: but so it is, that the *Bensil* of the Air G H, is equal in degree to the *Bensil* of the Air E F, according to the Theorem 21. Where it's said, that the Pressure of Fluids may be as much, in the least part, as in the whole: therefore the Pillar C D, and the Pillar A B, must be of equal weight, when both are weighed together in the opposite scales of a Ballance, which is false, seeing the one is far thicker, and so heavier than the other. There's no way to answer this objection, but by granting the Air G H, and E F, to be equal in *Bensil*, and yet the two Pillars unequal in weight, because according to the 22 Theorem, the *Bensil* of a Fluid is one thing, and the *natural weight* is another.

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### THEOREM XXXII.

*In all Fluids there is a Pondus and a Potentia, a weight and a power, counterpoising one another, as in the Staticks.*

**T**Hat part of the *Mathematicks*, which is called *Staticks*, is nothing else, but the *Art of weighing heavy Bodies*; in which, two things are commonly distinguished

E

guished, *viz.* the *pondus* and the *potentia*, the *weight* and the *power*. 'Tis evident, while two things are counterpoising one another in the opposite scales of a Ballance, as *Lead* and *Gold*, the one being the *pondus*, the other the *potentia*. The same two are as truly found in the *Hydrostaticks*: for while the Mercurial Cylinder is suspended in the *Torricellian Experiment*, by the weight of the Air, the one is really the *pondus*, the other the *potentia*. Or while into a *Siphon*, with the two orifices upward, Water is poured; there arises a counterpoise, the Water of the one Leg counterballancing the Water of the other, this taking the name of a *pondus*, the other the name of a *potentia*. 'Tis evident also, while a surface of Water, sustains a Pillar of Water, this being the *pondus*, that the *potentia*: Or, while a surface of Water sustains a Pillar of Air, the Pillar of Air being the *pondus*, and the surface of Water the *potentia*. Or, while a surface of Quick-silver sustains a Pillar of Water or Air, the surface is the *power*, and either of the two is the *pondus*, or *weight*, as you please.

### THEOREM XXXIII.

*Fluid Bodies can never cease from motion, so long as the pondus exceeds the potentia, or the potentia the pondus.*

**T**HIS is a sure Principle in the *Hydrostaticks*, which will appear most evident; while we pass thorow the subsequent Experiments, I shall only now make it appear by one instance, though afterwards by a hundred. In the *Torricellian Experiment*, lately mentioned, 'tis observed, that



that though the Pipe were never so long, that's filled with Mercury, yet the Liquor subsides, and falls down alwayes till it come twenty nine inches above the surface of the stagnant Mercury below. The reason whereof is truly this, so long as the Mercury is higher then the said point, as long doth the *pondus* of it exceed the *potentia* of the Air; therefore the motion of it downward can never cease, till at last by falling down, and becoming shorter, it becomes lighter, in which instant of time, the motion ends, both of them being now in *equipondio*, or in evenness of weight.

### THEOREM XXXIV.

*When two Fluids of different kinds are in æquilibrium together, the height of the one Cylinder is in proportion to the height of the other, as the natural weight of the one is to the natural weight of the other.*

For understanding this Theorem, we must consider, that when two Cylinders of the same kind, as one of Water with Water, or as one of Mercury with Mercury, are counterpoising one another, both are of the same altitude, because both are of the same natural weight. But when the two are of different kinds, as a Cylinder of Air with Mercury, or as a Cylinder of Air with Water, or as a Cylinder of Water with Mercury, then it will be found, that by what proportion, the one Liquor is naturally heavier or lighter, then the other, by that same proportion, is the one Cylinder higher or lower then the other. For example, because Air is reckoned 14000 times lighter then Quick-silver, therefore the Pillar of Air that counterpoiseth

poiseth the Pillar of Quick-silver in the *Torricellian Experiment*, is 14000 times higher. The one is 29 inches, and therefore the other is 406000 inches: which will amount to 33833 foot, or about 6766 fathom, counting five foot to a fathom. And because Air is counted 1000 times lighter then Water, therefore the Pillar of Air that sustains the Pillar of Water is 1000 times higher. The hight of Water by the Pressure of the Air is 34 foot, and therefore the hight of the Air is a thousand times 34 foot. And because Water is reckoned 14 times lighter than Mercury, therefore you will find, even by experience, that the Pillar of Water, that counterpoises the Pillar of Mercury, is 14 times higher. For if the Mercury be ten inches, the Water will be exactly 140. If it be 29 inches, the Water will be thirty four foot. The reason is evident, because if one inch of Mercury be as heavy naturally as 14 inches of Water, it follows of necessity, that for making of a counterpoise, to every inch of Mercury, there must be 14 of Water, and these in altitude, each one above another.

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Hydro-



# Hydrostatical EXPERIMENTS,

For demonstrating the wonderful  
*Weight, Force, and Pressure* of the  
Water in its own Element.

## EXPERIMENT I.

Figure 6.

**I**N explicating the *Phenomena* of the *Hydrostaticks*, and in collecting speculative, or practical conclusions from them, I purpose to make choise of the plainest, and most easie Experiments, especially in the entry, that this knowledge, that's not very common, and yet very useful, may be communicated to the meanest capacities. For, if at the first; any mystical, or abstruse Experiments, should be proposed with intricate descriptions, they would soon discourage, and at last hinder the ingenuous Reader from making progress.

gress. For, if a man do not take up distinctly, the Experiment it self first, he shall never be able to comprehend next the *Phenomena*, nor at last see the inferences of the conclusions. Next, though some of the *trials* may seem obvious, yet they afford excellent *Phenomena*, by which many profound Secrets of Nature are discovered. And if that be, 'tis no matter what kind they be of. Then, the grand design here, is not to multiply bare, and naked Experiments; for that's a work to no purpose, for it's like a foundation without a superstructure: but the intention is, not only to describe such and such *things*, but to build such and such Theorems upon them, and to infer such and such conclusions, as shall make a stately building, and give a man in a short time a full view of this excellent Doctrine.

For the first Experiment then, prepare a Vessel of any quantity, as A B C D, near half full of Water, whose surface is M H. Prepare also two Glass-pipes, the one wider, the other narrower, open at both ends, which must be thrust down below the Water, first stopping the two upper orifices E and F. This done, open the said orifices, and you shall see the Water ascend in the wider to G, and in the narrower to H. Now, the question is, What's the reason, why the Water did not ascend, the orifices E and F, being stopped, and why it ascends, they being opened? To the first part I answer, the Water cannot ascend, because the imaginary surface of Water L K is equally and uniformly prest: for with what weight the outward Water M L, and H K prest the said surface, with the same weight, doth the Air within the two Pipes prest it. To the second part I answer, the Water ascends, because the same surface (the orifices E and F being opened) is unequally prest:

prest: for the outward Water M L, and H K, prest it more, then the Air within the Pipes do. The difficulty only is, why it is equally prest, the orifices E and F being stopped, and why it is unequally prest, the said orifices being once opened. To unloose the knot, I must shew the reason, why the Air within the Pipes, prest the surface L K, with as great a burden, as the outward Water prest it. For understanding this, you must know, that when the orifice I is thrust down below the Water, there ariseth a sort of debate between the lower parts of the Water, and the Air within the Pipes, the Water striving to be in at I, and the Air striving to keep it out: but because the Water is the stronger party, it enters the orifice I, and causeth the Air retire a little up, one fourth part, or sixth part of an inch, above I, and no more, which is a real compression it suffers. For the orifice E being stopped, hinders any more compression, than what is said; in which instant of time the debate ends, the Air no more yeelding, and the Water no more urging; by which means the Air having obtained a degree of *Bensil*, more then ordinary, by the Pressure of that little quantity of Water, that comes in at I, presteth the part of the imaginary surface, it rests upon, with as great weight, as the outward Water presteth the parts it rests upon. But when the orifice E is opened, the outward water M L, and H K, prest the imaginary surface L K more, than the Air within the Pipe can do. And the reason is, because by opening the orifice above, the internal Air, that suffered a degree of *Bensil* more then ordinary, presently is freed, and consequently becomes of less force, and weight; which the Water finding, that hath a little entered the orifice I, instantly ascends to G, it being less pressed, then the Water

ter without the Pipe. Now the reason, why it ascends no higher then G, is taken from the equal Pressure of the Body that rests upon the surface MGH: For, as soon as it comes that length, all the parts of the horizontal Plain of Water, is uniformly prest with the incumbent Air, both within the Pipe, and without the Pipe. The Water in going up, cannot halt mid-way between I and G, for then there should be an unequal Pressure in Fluids without motion, which is impossible; for the Water is still stronger then the Air, till once it climb up to G.

From this Experiment we see first, that in Water there is a Pressure and Force; because having opened the orifice E, which is only *causa per accidens* of this motion, the Water is prest up from I to G. We see secondly, that Fluid Bodies, can never cease from motion, till there be an equal Pressure among the parts, which is evident from the ascent of the Water from I to G, which cannot halt in any part between I and G, because of an unequal Pressure, till it once climb up to G. We see thirdly, that Fluid Bodies do not sustain, or counterpoise one another according to their *thickness* and *breadth*, but only according to their *altitude*; because there is not here any proportion between the slender Pillar of Water HK within the Pipe, and the outward Water that sustains it, I mean as to the *thickness*; therefore 'tis no matter, whither the Glass Tubes be wider or narrower, that are used in counterpoising Fluid bodies one with another. And this is the true reason, why 'tis no matter, whither the Tub of the *Baroscope* be a wide one, or a narrow one, seeing the Air doth not counterpoise the Mercury, according to *thickness*, that's to say, neither the thickness of the ambient Air that sustains, nor the thickness of the Mercury that



is sustained, are to be considered; but only their *altitudes*. 'Tis true, the element of Air is fourteen thousand times higher, then the Mercurial Cylinder, yet there is a certain and true proportion kept between their heights; so that if the element of Air, should by *divine providence* become higher or lower, the height of the Mercury would alter accordingly.

## EXPERIMENT II.

Figure 6.

**T**AKE out of the Water, the wide Pipe EGI, and stopping the orifice I, pour in Water above at E, till the Tub be compleatly full. Having done this, thrust down the stopped orifice, I to the bottom of the Vessel, and there open it, then shall you see the Water fall down from E to G, and there halt. The reason is taken from unequal Pressure; for the Tub being full of Water from E to I, that part of the *imaginary* surface, upon which the Pillar of Water rests, is more burdened than any other part of it, namely more then L or K; therefore seeing one part is more burdened than another, the Cylinder of Water that causeth the burden, must so far fall down, till all the parts be alike prest, in which instant of time, the motion ceaseth. This leads us to a clear discovery of the reason, why in the *Baroscope*, the Mercury falls from the top of the Tub of any height, alwayes to the twentieth and ninth inch, above the stagnant Quick-silver. For example, fill the Pipe NQ, which is sixty inches high with Mercury, and opening the orifice Q, the Liquor shall fall out, and fall down from N, till it rest at R, which

F

is

is twenty nine inch above the open orifice Q. The reason is the same, namely unequal Pressure, seing one part of the *imaginary* surface of Air X S, upon which the Cylinder of Mercury stands, is more burthened then the other next adjacent: therefore, so long and so far must the Mercury subside and fall down, till the part Q, upon which the Basis of the Pillar rests, be no more burthened, than the rest of the parts; in which instant of time, the motion ceaseth, and there happeneth an equal ballance, between the Silver within the Tub, and the Air without. If it be said, I see a clear reason, why the outward Water M L, ought to sustain the inward G I, but cannot see, why the outward Air T Z S and V R X, ought to sustain the inward Mercury R X: neither do I see a reason, why it should halt at R, as the Water rests at G. I answer, though sense cannot perceive the one, as evidently as the other, yet the one is as sure as the other. For taking up the reason why it halts at R, 29 inches above X, you must remember, from the 25 Theorem, that the Pressure of the Air upon Bodies, is equivalent to the weight of 34 foot of VWater perpendicularly, or 29 inches of *Quick-silver*. The Pillars of Air then T Z S, and V R X, being as heavy each one of them, as two Pillars of Mercury, each one of them 29 inches high, it follows of necessity, that the Mercury within the Tub, must be as high as R. 'Tis no wonder to see the *Silver* halt at R, provided R X, and Z S, were two bulks of Mercury, environing the Pipe, as the outward VWater environs the wider and narrower Pipe. Neither ought any to wonder, when the *Silver* falls down, and rests at R, nothing environing the Pipe but Air, seing the Pressure of the Air is equivalent to the weight of 29 inches of *Quick-silver*.  
This

This Experiment is easily made: take therefore a slender Glass-pipe of any length, beyond 30 inches, open at both ends; but the lower end Q, must be drawn so small by a flame of a Lamp, that the entry may be no wider, than may admit the point of a small needle, or the hair of ones head. Then stopping the said orifice, pour in Mercury above at the orifice N, till the Pipe be compleatly full. Next, close the said orifice with wet Paper, and the pulp of your finger; and opening the lower orifice, you shall find, (which is very delightful to behold) the Mercury spring out, like unto a small silver thread, and falling down from the top N, shall rest at R, the motion ceasing at the narrow orifice Q. This shews evidently, that there is not need alwayes of stagnant Mercury, for trying the *Torricellian Experiment*; but only when the mouth of the Pipe below is wide: for being narrow, the *silver* runs slowly out, and consequently subsides slowly above, and coming down slowly to R, there rests. But when the mouth is wide below, the *silver* falls down so quickly, that it goes beyond R, before it can recover it self, which recovery would never be, unless there were stagnant Mercury to run up again.

From what is said, we see first, that when one part of a surface of Water or Air, is more burthened than another, the burthened part presently yeelds, till it be no more burthened than the other. This is clear from the falling down of the Water from E to G, which cannot be supported by the part I, because more burthened than the rest. We see secondly, that the element of Air, rests upon the surfaces of all bodies with a considerable weight; otherwise it could not sustain the Water, before it fall down from E to G: for if it did not rest upon the surface

M H, with weight, the Water could never be suspended; being the application of the finger to the orifice E, is only the *accidental cause* of this sustentation. We see thirdly, that according to the difference of *natural weight*, between two Fluids, so is the proportion of *altitudes* between two of their Cylinders; therefore Air being reckoned 14000 times lighter than Mercury, it follows that the Cylinder of Mercury sustained by the Air, must be 14000 times lower and shorter, than the Cylinder of Air that sustains it, which appears from this experiment to be true, seeing by the Pressure of the Air, which is thought to be about 7000 fathom high, 29 inches of Mercury is supported between R and X. In a word, if Air be naturally 14000 times lighter than Mercury, which is very probable; then must the altitude of it, commonly called the *Atmosphere*, be fourteen thousand times, nine and twenty inches, that is 406000, or of feet 33833.

### EXPERIMENT III.

Figure 6.

WHILE the outward, and inward Water are of the same altitude, withdraw the inward Air E G by suction, or by any other device you think fit, and you will find the Water rise as high as E, which I suppose to be 34 foot above M G H. The same *Phenomenon* happens, in taking the Air out of the narrow Pipe F K. The reason is still unequal Pressure; for in removing the Air, that's within the Pipe, the part of the surface M, and the part H, remains burthened, while the part G is freed of its burden: therefore this part of the surface, being liberated

rated of its burden, that came down through the Pipe, instantly rises, and climbs up as far, as the outward Air resting upon M and H, can raise it, which is to E 34 foot: for the Pressure of the Air upon the surfaces of all Waters, according to the 25 *Theorem*, being equivalent to the weight of 34 foot of Water, must raise the said Water in the Pipe 34 foot. You do not wonder, why it rises from I to G, as in the first experiment; no more ought you to wonder, why it rises from G to E, seeing the weight of the Air, doth the same thing, that 34 foot of Water resting upon the surface M H, would do.

From this experiment we see first, that the Pressure of the Air, is the proper cause of the motion of Water, up thorrow *Pumps* and *Siphons*, or any other instrument, that's used in Water-works of that kind, for if the weight of the Air, resting upon the surface M H be the cause, why the Water climbs up from G to E, the same must be the cause, why the stagnant Water follows the *Sucker* of the *Pump*, while it's pulled up. And the same is the cause, why Water ascends the Leg of a *Siphon*, and is the cause, why motion continues after suction is ended. We see secondly, that every Pressing Fluid hath a *Sphere of activity*, to which it is able to raise the Fluid, that is pressed. This is evident in this experiment, because the Pressure of the Air resting upon M H, is able to raise the Water, the height of E in the wide Pipe, and the height of F in the narrow, and no further, even though the said Pipes were far longer: and this altitude and highest point is precisely 34 foot between Air and Water. We see thirdly, that 'tis all one matter, whether *Pumps* and *Siphons* be wider or narrower, whether the tub of the *Baroscope* be, wherein the Mercury is suspended, of a large Diameter, or of a lesser Diameter.

Diameter. This is also evident from the same experiment; seeing there is no more difficulty in causing the Water ascend the wide Pipe, than in causing it ascend the narrow one. And the reason is, because the pressing Fluid respects not the pressed Fluid, according to its *thickness* and *breadth*; but only according to its *altitude*. Therefore 'tis as easie for the Air, to press up Water through a *Pump* four foot in Diameter, as to press it up through a *Pump*, but one foot in Diameter.

## EXPERIMENT IV.

Figure 7.

**T**His Schematism represents a large Vessel full of Water, whose first and visible surface is DEHK. The second, that's imaginary is, LI, six foot below it. The third of the same kind, is MG, six foot lower. The fourth, is NFO, six foot yet lower. The last, and lowest, is ABC. There are here also four Tubes, or rather one Tub under four divers positions, with both ends open. After this Tub DA is thrust below the Water, till it ascend, as high as D in it, lift it up between your fingers, till it have the position of the second Pipe EF, and then you shall see, as the orifice of the Pipe ascends, the Cylinder of Water fall out by little and little, until it be no longer than EF. Again, lift it further up, till it have the position of the Pipe HG, then shall you find the Cylinder of Water become yet shorter. Lastly, if it be scituated, as the Pipe KI, the internal Water becomes no longer than KI. The reasons of these *Phenomena* are the same, namely unequal Pressure; for the Orifice A being lifted up as high



high as F, it comes to the imaginary surface N O, which is not under so much Pressure, as the other is; therefore one part of it being more burdened, than another, namely the part upon which the Cylinder of Water rests, it presently yeelds, and suffers the Cylinder to become shorter, and lighter, till it become no heavier, then is proportionable to its own strength. To make this reason more evident, it is to be noted, that no surface of Water is able to support a Cylinder higher then its own deepness, that is to say, if a surface be 40 foot deep, it is able to sustain a Cylinder 40 foot high, and no more: therefore the surface N O, being but 18 foot deep, it cannot sustain a Cylinder 24 foot long: for if that were, then the *Potentia*, should be inferior to the *Pondus*, which is impossible in the *Hydrostaticks*. In effect, it were no less absurdity, then to say, 18 ounces are able to counterballance 24. For a second trial, lift up the same Pipe higher, till it acquire the position of the Tub G H; in this case, the Cylinder of Water within it, becomes yet shorter, even no longer, than G H. The reason is the same, namely unequal Pressure; for when a Cylinder of Water 18 foot high, comes to rest upon this surface, that is but 12 foot deep, it makes one part of it more burdened then another; therefore the part that is more prest; presently yeelds, and suffers the Cylinder to fall down, till the *Pondus* of it, become equal to its own *Potentia*. For the last trial, lift up the Tub, till it acquire the position of the Pipe K I: in this case, the Water within it becomes no longer then K I, the surface L I, that is but six foot deep, not being able to sustain a Cylinder 12 foot high.

From this Experiment we see first, that in all Fluid Bodies there is a Pressure, which is more or less, according to  
the

the deepness of that Fluid; this is evident from the four severall surfaces; there being more Pressure and force in the lowest A B C, then in the next N O; and more in this, then in the surface M G; and more in this, then in L I. We see secondly, that in all Fluids, there is a *Pondus* and a *Potentia*; which two are alwayes of equal force, and strength; the *Potentia* is clear and evident in the surface, by supporting the Pillar; which Pillar is nothing else, but the *Pondus* supported. And that they are alwayes of equal strength, is most evident also; for when you endeavour to make the *Pondus* unequal to the *Potentia*, in making a surface 18 foot deep, to support a Pillar 24 foot high, they of their own accord become equal; the Pillar becoming shorter, and suitable to the strength of the surface that sustains it. We see thirdly, that 'tis impossible for one part of the same Horizontal surface, to be more burdened then another: for when you endeavour to do it, by setting a longer Pillar upon it, the part burdened instantly yeelds, till it be no more prest, then the next part to it. We see fourthly, that the inequality, that is between the *Pondus* and the *Potentia* in Fluids, is the proper cause of the motion of Fluids. For when you endeavour to make a surface 30 foot deep, sustain a Pillar 40 foot high, this inequality is the true cause, why the Pillar subsides, and falls down, and why the surface yeelds, and gives way to it. And this inequality is the true cause, why the motion of Water thorow *Siphons* continues. For understanding this, you must conceive a *Siphon*, to be nothing else, but a crooked Pipe with two legs, the one drowned among Water, the other hanging in the open Air. The use of it is, for conveying Wine or Water from one Vessel to another, which is easily done by suction. Now after suction is ended,

ed, the motion of the Water continues, till the surface become lower, then the orifice out of which it runs. The true reason then, why the Water flows out, is the inequality between the *Potentia* of the Air, and the *Pondus* of the VVater; the *Pondus* being stronger then the *Potentia*. For in Air as in VVater, we must conceive Horizontal surfaces; and these surfaces to be endowed with Pressure and force, as are the surfaces of VVater. Now when the leg of a *Siphon* is hanging in the Air, it must rest upon one surface or another, and consequently the VVater in it, must rest upon the same surface. If the *Potentia* of the surface be stronger, then the *Pondus* of the VVater; the VVater is driven backward, which alwayes comes to pass, when the orifice is higher, then the surface of the VVater of the Vessel, among which the other leg is drowned. If the *Potentia* of the surface of that Air, be of equal power and strength, with the *Pondus* of the VVater, the VVater goeth neither backward, nor forward, but stands in *equilibrio*: this happens, when the orifice is neither higher, nor lower, than the surface of the VVater in the Vessel. But if the *Potentia* of the surface of the Air be weaker, than the *Pondus* of the VVater; in this case, the Air yeelds, and suffers the VVater to run out, even as a surface 30 foot deep, yeelds to a Pillar of VVater 40 foot high. The same inequality is the reason, why VVater climbs up the Pump; why VVater climbs up a Pipe, when a man sucks with his mouth. Before suction, the *Potentia* that's in the surface of VVater, among which the end of the Pipe is drowned, is of equal force with the *Pondus* of the Pillar of Air, that comes down thorow the Pipe, or Pump; but as soon as a man begins to suck, the said Pillar of Air becomes lighter; and the VVater finding this, presently ascends. The same

is the reason, why the Mercury falls down to 29 inches in the *Baroscope*, and no further: for as long as the *Pondus* of the Pillar of Mercury, exceeds the *Potentia* of the surface of Air, so long doth the motion continue; and when both are become equal in force, the motion ceaseth. VVhen the Glass-tub is 40 inches long, and filled with Mercury, and inverted after the common manner, you are endeavouring as it were, to cause a surface 29 inches deep; sustain a Pillar 40 inches high, which is utterly impossible in Fluids. It is judged by many a wonder to see the descent of the Mercury in the *Baroscope*; but in effect, there's no more cause of admiration in it, than to see the Cylinder of Water grow shorter, by lifting the Pipe up from one surface to another.

From this Experiment, we see the true reason, why the Mercurial Cylinder of the *Baroscope* becomes shorter and shorter, according as a man climbs up a mountain with it. For at the root of the hill, the surface of Air, that sustains the Pillar of Mercury, is of greater force, than the surface at the middle part: and this is stronger than any surface at the top. The Pipe therefore being carried up from one surface to another, the Mercury in it, must subside, and fall down, even as the Water falls down, and becomes shorter, by lifting the Pipe from the surface A B C D to the surface N O. And as the whole VVater would fall down, if the orifice I, were lifted above the surface D E H K, so if the *Baroscope* could be carried so high, till it came above the top of the Air, the whole Mercurial Cylinder would surely fall down. And as by thrusting down the said Pipe to the bottom of the Vessel again, as the Pipe D A, the VVater ascends in it; so by bringing down the *Baroscope* to the earth again, the whole 29 inches would rise again.

E X P E -

## EXPERIMENT V.

Figure 8.

**F**ill the Vessel *A D G H* with *VV*ater to the brim. Next, thrust down the open orifice of the Tub *D A*, to the bottom, and you shall see the *VV*ater ascend in it, as high as *D*, according to the first experiment. When this is done, recline the said Pipe, till it ly as *B E*, and you shall find the Pipe, compleatly full of *VV*ater. Next, erect the same Tub again as *D A*, and you shall see the Cylinder of *VV*ater fall down, and become shorter, as at first. For salving this *Phenomenon*, and such like, I must suppose this *VV*ater to be 50 inches deep, and the Tub *I A*, and *B E* 90 inches long: and the said Tub in reclining, to describe the quadrant of a Circle *F E G*. Now the question is, why there being but 50 inches of Water in the Tub, while erected, there should be 60 in it, when it is reclined? Secondly, why there should be 90 inches of Water in the Tub *B E*, and but 50 in it, when it stands Perpendicular, as *D A*? If you reply, because there are 90 inches in *recta linea* between the point *B*, and the point *E*, and but 50 between *A* and *D*. But this will not answer the case, because, if you stop the orifice *E*, with the pulp of your Finger, before it be erected, you will find the Tub remain full of *VV*ater, even while it stands Perpendicular; and fall down, when the orifice is opened. Or, while the Tub stands Perpendicular, stop the orifice *I*, and recline it as *B E*: yet no more Water will be found in it, than 50 inches: but by unstopping the said orifice, the *VV*ater climbs up from *R* to *E*, and becomes 90 inches. Now, what's the reason,

G 2

why

why it runs up from R to E, and why it falls down from I to D? I answer then, the VVater must run up from R to E, because of the inequality, that's between the *Pondus* of the Cylinder B R, and the *Potentia* of the surface of VVater A B C, that supports the said Cylinder. For understanding this, know, while the Tub is erected, there is a perfect equality, between the weight of the Pillar A D, and the force or *Power* of the surface that sustains it, seeing a surface 50 inches deep, supports a Pillar 50 inches high. But as soon as the Tub is reclined, there arises an inequality between the saids two parties, the *Pondus* of the Cylinder becoming now less than before. If you say the quantity of the VVater is the same, namely 50 inches, in the reclined Tub, as well as in the Perpendicular. I grant the quantity is the same, but the weight is become less. Now the reason, why the same individual VVater, is not so heavy as before, is this; there are 40 ounces of it, supported by the sides of the Tub within; which were not, while the Tub was erected: for in this position, the whole weight of the Cylinder rests upon the surface: but while the Tub is reclined, the said surface is eased, and freed of 40 ounces of it; this 40, resting and leaning upon the sides of the Pipe within. The surface then, finding the said Cylinder lighter now than before, instantly drives it up from R to E, 40 inches. And likewise, when the reclined Pipe is made Perpendicular, the Water falls down from I to D, because of the inequality, that's between the *Pondus* of the Pillar, and the *Potentia* of the surface; this surface 50 inches deep, not being able to support a Pillar 90 inches high, for if this were, then one part, should be more burthened than another, which is impossible.

It is to be observed, that by how much the more, the  
Tub



Tub is reclined from a Perpendicular, towards the horizontal surface A B C, by so much the more grows the inequality, between the *Pondus* and the *Potentia*, and that according to a certaine proportion. Hence is it, that the Tub being reclined from 60 degrees to 50, there arises a greater inequality between the *Pondus* of the Cylinder, and the *Potentia* of the surface, than while it is reclined from 70 to 60: and more yet in moving from 50 to 40, than in moving from 60 to 50, and so downward, till it be horizontal, in which position, the whole *Pondus* is lost. And contrariwise, while the Pipe is elevated, the *Pondus* begins to grow; and grows more, being lifted up from 10 to 20, than from 1 to 10: and yet more in travelling from 20 to 30, than from 10 to 20, and so upwards, till it be Perpendicular, in which position, the Cylinder regains the whole *Pondus* and weight, it had. This proportion is easily known, for its nothing else, but the proportion of *Versed Sines* upon the line F B; for according to what measure, these unequal divisions become wider, and wider from 90 to 1, according to the same proportion does the *Pondus* of the Cylinder become less and less: and contrariwise, according to what proportion the said divisions become more and more narrow from 1 to 90, according to the same measure and rate, does the *Pondus* of the Cylinder become greater and greater.

From this experiment we see first, that two Cylinders of Fluid bodies; differing much in quantity, may be of the same weight: because though the Cylinder B E 90 inches long, be far more in quantity; than the Cylinder D A, that's but 50, yet both of them are of the same weight, in respect of the surface that sustaines them. If it be said, the one is really heavier, than the other, notwithstanding of all.

all this. I answer, it is so indeed, in respect of the *Libra*, or Artificial Ballance, that we commonly use in weighing of things: but it is not so in respect of this *Natural Ballance*, if I may so speak, wherein Fluid bodies are onely weighed after this manner. We see secondly a clear ground for setting down the ninth Theorem; namely, that in all Fluid bodies a twofold weight may be distinguished, one *Sensible*, another *Insensible*: because the *Sensible* weight of the Cylinder of Water B E, remains still the same, even though it should be reclined to G; for take it out, and weigh it in a Ballance, it will be as heavy the one way as the other. But it is not so with the *Insensible* weight, seeing the Tub begins no sooner to recline, but as soon it begins to diminish, and grows less. This *Insensible* weight is nothing else, but the *sensible* weight considered after another manner. For look upon the weight of the Pillar of Water B E, as it weighs in a pair of Scales, it is then *Sensible*, and weighs so many ounces, and cannot be more or less: but look upon it in reference to the *Potentiæ* of the surface, that sustains it, it is then *Insensible* as to us: for though a man should put his hand below the Water, and endeavour to find the weight of the said Pillar, yet he shall not find it, though that part of the surface upon which it rests, doth really (if I may so speak) find the weight of it. And as it is *Insensible*, so is it sometimes more, and sometimes less, according as the Tub is elevated, or reclined: now these two being put together, gives a very probable ground for this distinction. We see thirdly, that the *Pondus* or weight of Fluids, doth not only press according to Perpendicular lines; but according to lines falling obliquely upon the imaginary surface; so doth the weight of the Pillar of Water B E, press the surface A B C. We see fourthly, that Fluid

Fluid Bodies, do counterpoise one another according to *Altitude* only: for put the case, the Pipe B E, were ten times wider then it is, yet will the surface sustain the Water in it, provided the Pipe keep still the same position of *Altitude*, namely 50 degrees: the reason seems to be this, for if the *Base* of the Pillar become more in Diameter, it necessarily requires a larger part of the surface to rest upon; which larger part is really stronger than the lesser part, as will be shewed afterwards. From this Experiment we see lastly, an evident reason, why the Mercurial Cylinder in the *Baroscope* runs up, and fills the empty space, when the Pipe is reclined, and why it runs down, when the Tub is erected again. In effect, the reason is the same, namely, an inequality between the *Pondus* of the Quick-silver, and the *Potentia* of the surface of the Air: for when the Tub begins to recline, the *Pondus* begins to rest upon the side of the Tub within; By which means the *Potentia* of the surface finding the burden less, instantly thrusts up the stagnant Mercury to supply that loss, seeing two Fluids cannot counterpoise one another, unless they be in *aquilibrio*. And contrariwise, as soon as the Tub begins to be erected, the *Pondus* of the Mercury begins to grow, and so overcomes the *Potentia* of the surface, till by falling down it can do no more.

## EXPERIMENT VI.

Figure 9.

**T**His Schemarism represents a Vessel full of Water, whose first and visible surface is H I K, the second, which is imaginary, is E F G; the third, A B C D. Besides

Fig. 5.

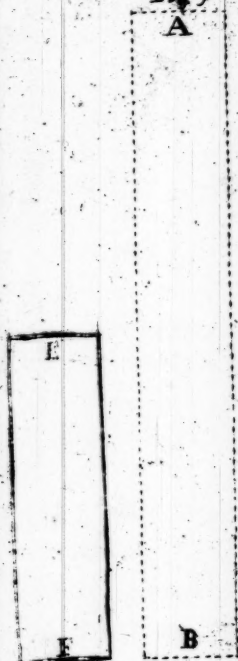


Fig. 32



Fig. 6

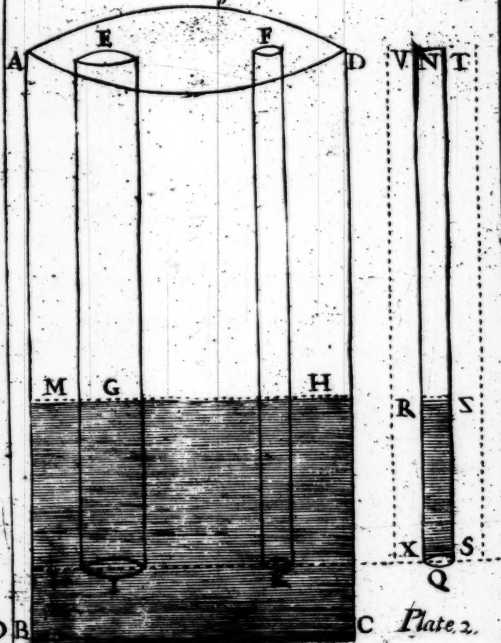


Fig. 37

Fig 7

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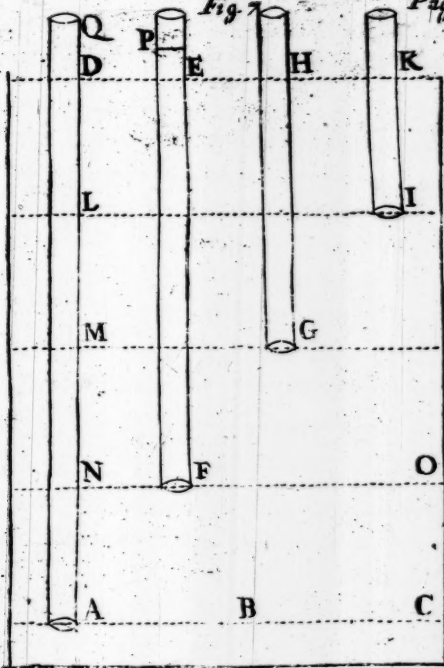
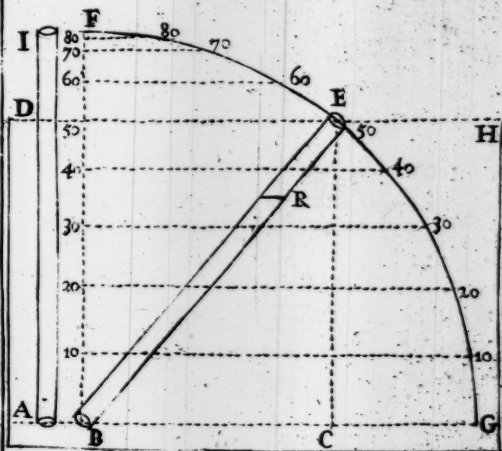


Fig 8

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Besides these three in Water, conceive a fourth in the Air, above the Water, namely *L M N*. Upon this aerial surface, rests the orifice *M*, of the Tub *T M*, open above. Upon the surface *E F G*, is standing the mouth *F*, of the Pipe *S F*. And upon the surface *A B C D*, stands the Pipe *R B*, open at both ends. After the orifice *B* is drowned below the *VV*ater, you will find the Liquor rise from *B* to *H*. Then close with the pulp of your Finger the mouth *R*, and lift the Pipe so far up, till it have the Position of the Pipe *S F*; and you shall see the *VV*ater hing in it between *F* and *O*. Lastly, bring the said orifice complearely above the *VV*ater, till it have the position of the Tub *T M*; yet shall the *VV*ater still hing in it, as *M P*. The first question is, what sustains the *VV*ater *O I*; for the part *F I*, is sustained by the ambient *VV*ater: I answer, it cannot be the pulp of the Finger closing the orifice *S*; for though, by taking away the Finger, the *VV*ater *O I* falls down, and by putting to the Finger, it is kepted up, yet this proves not the pulp of the Finger to be the principal, and immediat cause. I say then, the *VV*ater *O I* is suspended by the weight of the incumbering Air, resting upon the surface *H I K*. For understanding this, consider, as I said before, 25. Theorem, that the Pressure of the Air upon all Bodies, is just equivalent to the weight of 34 foot of *VV*ater. Hence then is it, that if the Air be able to sustain a Pillar of *VV*ater, 34 foot high, it must be able to sustain the short Pillar *O I*, that exceeds not four foot. The second question is, whether the part *F*, be equally burthened with the part *E*, or *G*; for it would seem not, seing the *VV*ater *O I F*, is but four foot high; whilst upon *E* or *G* is resting, not only more then a foot of *VV*ater to the top *H I K*, but the



the whole weight of the *Atmosphere* upon the said top is resting, which is equivalent to the burden of 34 foot of VVater. I answer, there's more to be considered, than that four foot of VVater, which in it self is but of small burden, therefore to this we must add the weight of the Air between O and S, within the Pipe (remember that the orifice S is stopped with the pulp of the Finger) which in effect will be as heavy as 31 foot of VVater. Put the case then, F, to be one foot below the first surface H I K, and the VVater O I to be three foot, then ought the Air O S, to have the weight of 31 foot, because the surface E F G is able to support a Pillar of 35 foot. This I prove, because the part E, *de facto*, sustains 35 foot, because the Air above is equivalent to 34 foot of it, and there is a foot of VVater between it and the top, namely between E and H. The third question is, how it comes to pass, that the Water still remains in the Pipe, after the orifice M is brought above the surface of the Water; for there is here no stagnant Water guarding it, as guards the orifice F. I answer, that the *base* M, of this Pillar of Water P M, as really rests upon the horizontal surface of this Air L M N, as a Cylinder of Brass or Timber rests upon a plain Marble Table, and after the same manner. Remember that the orifice T is stopped all this time, with the pulp of the Finger. If it be said, that the part M, is more burdened then the part N, seeing it sustains four foot of Water, which the part N supports not, and the Air P T within the Pipe also, which is of as much *Bensil* and Pressure, as the Air N Y is of. For clearing of this difficulty, consider, that the Pillar P M is shorter now than before, for the orifice M coming up from D, some inches of Water falls out, as will be found by experience. Suppose

pose then, that of four foot, six inches fall out; if this be, then the inclosed Air between P and T, must be six inches longer, if this be, then of necessity the *Bensil* of it must be proportionably remitted and slackened: whence follows by *Metaphysical* necessity, that it cannot burden the Water P M, with as much weight as it had, and consequently the surface of Air cannot be so much burdened. It must then be no more burdened with them both together, than it is with the single Pillar of Air Y N. If then the Water P M, be three foot and an half, the weight of the enclosed Air T P, must be exactly the weight of thirty foot of Water and an half.

From this experiment, we see first the Pressure of the Air, for by it the Water O I is suspended, and by the same pressure is the Water P M suspended. We see secondly, that in Air, there is a power of dilating it self, and that this dilatation never happens, without a relaxation of the *Bensil*. We see thirdly, that one Fluid cannot sustain another, unless the *Potentia* of the one, be equal to the *Pondus* of the other, as is clear from the Aërial surface, that cannot sustain the whole four foot of Water, but suffers six inches of it to fall out, that the *Pondus* of the rest, and the Air above it, may become equal to its own *Potentia*. We see fourthly, that Fluid Bodies have not only a power of pressing downward, but of pressing upward likewise: as is clear from the Water O I, that's suspended by the Air pressing down the surface of Water H I K. It presseth upward also, while it supports the Water P M. This Experiment also answers a case, namely, whether or not, it is always needful to guard the orifice of the Tub of the *Baroscope* with stagnant Quick-silver? I say then, it is not always needful, provided the orifice be of a narrow diameter;

diameter; for experience tells, that while it is such, the Mercury will subside, and halt at 29 inches above the orifice, though no stagnant Mercury be to guard. In making this trial, the orifice must be no wider, than may admit the point of a needle. Or suppose it to have the wideness of a Tobacco-pipe, yet will the Mercury be suspended, though the end be not drowned among stagnant *Quick-silver*, even as the Water P M, is kept up without stagnant Water about it. For trial of this, you must first let the end of the Pipe, be put down among stagnant Mercury, and after the Cylinder is fallen down to its own proper altitude, lift up the Pipe slowly, till the orifice come above the surface, and you will find, provided you do not shake the Pipe, the Cylinder to be suspended after the same manner, immediately by the Air, as the Water P M is.

## EXPERIMENT VII.

Figure 10, 11.

**T**AKE a Vessel of any quantity, such as A B C D E, and fill it with VVater. And a Glas-pipe, such as G F D, of 15 or 20 inches long, of any wideness, close above, and open below. Before you drown the open end among the VVater, hold the Glas before the fire, till it be pretty hot, and having put it down, you will see the VVater begin to creep up till it come to F, where it halts. The question now is, what's the reason, why the VVater creeps up after this manner, 10 or 12 inches above the surface A B? I answer, the heat having rarified the Air within, and by this means, having expelled much of it, and the Air now contracting it self again with cold, the

Water ascends, being prest up with the weight of the incumbent Air, resting upon the surface of Water A B. There is here surely an inequality between a *Pondus* and a *Potentia*, that must be the cause of this motion. I judge then the inequality to consist between the weight of the Air within the Pipe, and the surface of Water C D E. To explicate this, I must suppose the Pipe to be thrust down cold; in this case, little or no Water can enter the orifice D. And the reason is, because the *Pondus* of the Air within the Glass, is equal to the *Potentia* of the surface C D E. But when the Pipe is thrust down hot; much of the Air having been expelled by the heat, and now beginning to be contracted by cold, the *Pondus* of the Air becomes unequal to the *Potentia* of the surface, and therefore this, being the stronger party, drives up the Air within the Glass, till by this ascent, the *Pondus* of the Air G F, and the *Pondus* of the Water F D together, become equal to the *Potentia* of the surface C D E, that sustains them. For a second trial; bring a hot coal neat to the side of the Glass, between G and F, and you will find the Water to creep down from F toward the surface A B; and if it continue any space, it will drive down the whole Water, and thrust it out at D. To explicate this, I must suppose that heat, by rarifying the Air within the Glass, intends and increaseth the *Bensil* of it, and the *Bensil* being now made stronger, there must arise an inequality between the *Pondus* of the said Air, and the *Potentia* of the surface C D E; the Air then, being the stronger party, causeth the surface to yeeld.

By comparing this Experiment with the former, we see a great difference between the dilatation of Air, of its own accord, and by constraint. For while it is willingly expanded,

panded, the *Bensil* begins to grow slack, and remiss, and loseth by degrees of its strength; even as the *Spring* of a *Watch* by the motion of the *Wheels*, becomes remiss. But when the dilatation is made by heat, and the Air compelled to expand and open it self, the *Bensil* becomes the stronger, and the Pressure the greater. Notwithstanding, though the *Bensil* of this inclosed Air *G F*, may be made stronger by heat, to the expulsion of the Water *F D*, yet if this rarefaction continue any time, the *Bensil* becomes dull and slack. And the reason is, because Air cannot be expanded and opened to any quantity; an inch cannot be dilated and opened to an hundred, or to a thousand: neither can the *Bensil* of it be intended, and increase to any degree, *v.g.* from one to 20, 30, or 100. And therefore, as the expansion grows, the *Bensil* must at length slacken. But if so be the Air were inclosed, as in a bladder knit about the neck with a string, then the more heat, the more *Bensil*: for in this case there is a growth of Pressure, without dilatation. And sometimes the *Bensil* may be so intended with the heat, that the sides of the bladder will burst asunder.

From this Experiment we see first a confirmation of the 21 Theorem, namely, that there may be as much *Bensil* and Pressure, in the smallest quantity of a Fluid, as in the greatest; as is clear from the *Bensil* of the Air *G F*, which in effect counterpoiseth the weight of the whole *Atmosphere*, resting upon the surface of Water *A B*. We see secondly, that when the *pondus*, and the *potentia* of two Fluids, are in *equilibrio*; or of equal strength, a very small addition to either of them, will cast the ballance. For if a man should but breath softly upon the side of the Glass between *G* and *F*, or lay his warm hand to it, the said Air will presently dilate it self, and by becoming thus stronger,  
thrust

thrust down the Water, and so overcome the *potentia* of the surface. We see thirdly a confirmation of the sixth Theorem, namely, that the Pressure of Fluids is on every side, as is clear from the inclosed Air G F, that not only presseth down the Water F D, but with as great force presseth up the top of the Glas within, and presseth upon all the sides of it within, with the same force. This Experiment also, leads us to the knowledge of two things: First, of the reason, why with cold the Water ascends in the common *Weather-glasses*; and why in hot weather the Water descends. Secondly, from this Experiment we may learn to know, when the Air is under a greater Pressure, and when under a lesser: because when the Air becomes heavier, as in fair weather, the Water creeps up in some measure, it may be two or three inches; when there is no alteration as to heat and cold: and in foul weather, or in great winds, when the Air is really lighter, the said Water creeps down as much. If it be asked, how shall I know, whether it be the cold of the Air, or heaviness of the Air, that causeth the Water to ascend; and whether it be the heat of the Air, or the lightness of the Air, that causeth the Water to descend? I have proposed this question of purpose, to let you see a mistake. Many believe, that the ascent and descent of Water in common *Weather-glasses*, is allannerly from the heat and coldness of the Air; and therefore they conclude a cold day to be, because the Water is far up: whereas the Water hath ascended since the last night, by reason of a greater weight in the Air, which alwayes is, when the weather is dry, and calm, though there hath been an alteration of heat to cold. If it be asked, how come we to the knowledge of this, that the pressure and weight of the Element of Air, is some-  
times



times less, and sometimes more? I answer, this secret of Nature, was never discovered, till the invention of the *Torricellian Experiment*, otherwise called the *Baroscope*. For after the falling down of the *Quick-silver* to 29 inches; if you suffer it to stand thus in your Parlour or Chamber, according as the Pressure, and weight of the Element of Air, becomes more or less, so will the Altitude of the Mercury become less or more, and vary sometimes above 29 inches, and sometimes below. This alteration is very sensible, which is sometimes the tenth part of an inch, sometimes the sixth, and sometimes the third, according as the weight of the Air is less or more. From *December* to *February*, I found the alteration become less and more from 30 inches to 28, which will be three fingers breadth. The common *Weather-glasses* then are fallacious, and deceitful, unless they be so contrived, that the Pressure of the Air cannot affect them, which is easily done by sealing them *Hermetically*, and in stead of common Water, to put in *Spiritus Vini rectificatissimus*, or the most excellent Spirit of Wine, and strongest that can be made.

It may be here inquired, whether or not, Mercury would ascend in this Glass, as the Water does? I answer it would, because the ascent depends only upon the Pressure of the Air, incumbering upon the stagnant Liquor in the Vessel, that's able to drive up Mercury as well as Water. It may be inquired secondly, how far Mercury will ascend, and how far Water will creep up? I answer, Mercury can ascend no higher in a Tub, than 29 inches; and Water no higher, than 34 foot; and this onely happens, when there is no Air above the tops of the Cylinders to hinder their ascents. But when there is Air, as GF above the liquor, it can go no higher, than the point to which the cold is able

able to contract the inclosed Air, which is in this Glass, the point F. It may be inquired thirdly, which is the greater difficulty, whether or not Mercury, will rise as easily in a Tub as Water; for seeing, its 14 times heavier, it seemes the Air should have greater difficulty to press it up, than to press up Water? I answer, 'tis greater difficulty for the Air to press up 20 inches of Mercury, than to press up 20 inches of Water; yet its no greater difficulty, for the Air to press up 20 inches of Mercury, than to press up 23 foot of Water, because the burden and weight is the same. It may be inquired fourthly, whether or not, it be as easie for the Air, to press up a thick and gross Cylinder of Water, as to press up a thin and slender one? For example, whether is it as easie for the Air to press up a Cylinder of Water 10 inches in Diameter, and 10 foot high, as it is to press up one, two inches in diameter, and 10 foot high? I answer, there is no more difficulty in the one, than in the other: and the reason is, because Fluid bodies do not counterpoise one another according to their *thickness*, but only according to their *altitude*, according to the fourth Theorem. Therefore seeing the slender Cylinder is as high as the grosser, it must be no more difficult to the Air, to press up the one then the other.

There is one difficulty yet remaining, which is truly the greatest of all; namely what's the reason, why its more difficult to the Air, to press up 20 inches of Mercury, than to press up 20 inches of Water: or more difficult to the Air, to press up 20 inches of Mercury, than to press up 10? I answer, this comes to pass, because the Air is more burthened with 20 inches of Mercury, than with 10. Now, if this be, then surely it must be more hard to the Air, to do the one, than to do the other: even as it is more hard;

hard; for a man, to lift up from the ground, 20 pound of iron, than to lift up 10 or 15. The case may be better illustrated after this manner. Suppose a man standing on the ground, with a rope in his hand, coming down from a Pulley above, drawing up a weight to the top of the house: put the case likewise, the weight be a stone of 20 pound, and the weight of it, to increase successively, as it is pulled up. Now its easie for the man to pull up the stone the first fathom; because it is but 20 pound weight: but the stone becoming 40 pound in the second fathom, and 60 in the third, and 80 in the fourth and so forth, untill it become 1000, he will find the greater difficulty, the longer he pulls. 'Tis just so with Air, or Water, raising Mercury in a Tub; for as the Cylinder of the Mercury grows higher by rising, so it becomes heavier, and consequently the imaginary surface, upon which the *Base* of the Pillar rests, is more and more burdened, and so becomes less and less able to press it up. This leads us to a clear discovery of the reason, why 'tis more difficult by suction, to pull up Mercury in a Pipe, than to pull up Water; and more hard to suck up ten foot of Water, then to suck up five. For trial of this, which is soon done, take a slender Glass-pipe 30 or 40 inches long, open at both ends, and drown the one end among *Quick-silver*, and put your mouth to the other, and having sucked, you will find greater difficulty to pull up thorow the Pipe 15 inches of Mercury, than to pull up 10, or 8; and far greater difficulty to suck up 20, than to pull up 15. It may be objected, that if a man had strength sufficient in his Lungs, to suck out the whole Air of the Pipe, thirty inches of Mercury would come as easily up, as three; which seems to prove, that the difficulty of the Mercurie's up-coming, depends not upon the weakness of

the Air, but upon the weakness of the Lungs, and want of strength to suck. I answer, though a man were able to suck out the whole Air of the Pipe, yet 30 inches, will never ascend so easily, as ten, nor ten so easily as three, and that for the reasons already given. But why is it then, (say you) that the stronger the suction be, the higher the Mercury ascends in the Pipe? I answer, the suction serves for no use, but to remove the impediment, that hinders the Mercury from coming up, which is nothing else, but the Air within the Pipe. Now, the more of this Air that's taken away by suction, (the stronger the suction is, the more Air is taken away) the sarder up comes the Mercury. But why ought there to be difficulty in the suction of Mercury, to the altitude of 15 or 20 inches, more than in the suction of Water to that altitude? I answer, when I suck Water up thorow a Pipe, the suction of the Air above it, is easie; because the ascending Water helps much to drive it up to the mouth, the outward Air driving up both. But the suction is difficult in Mercury, because the ascending liquor, does not help so much, to drive up the Air to the mouth, as the Water does. And the reason is, because the Air, being more burdened with 15 inches of Mercury, than with 15 inches of Water, cannot so easily drive up the one as the other, and so Mercury cannot so easily drive up the Air of the Pipe to the mouth, as Water does. In a word, according to the difference of *specifick weight*, between Water and Mercury, so is the difficulty of suction; therefore, because Mercury is 14 times heavier than Water, there is 14 times more difficulty, to pull up the one, than the other. Note, that *suction* is not taken here strictly, as contradicting *pulsion*; but in a large sense, as it may comprehend it.

To

To proceed a little further, let us suppose the Pillar of Mercury (see the 11. Figure) *GH*, that's raised by the surface of Air *FG*, to be 29 inches, and every inch to weigh one ounce. Secondly, that the said surface has 29 degrees of power or force in it: for in all counterpoises the *Pondus* and the *Potentia* are equal; therefore, if the Mercury be 29 inches, the *Potentia* of the surface must have 29 degrees of strength or force in it, to counterballance the *Pondus*. These things being supposed, which are evident, let us imagine the surface of Air, to raise the Mercury one inch above *FG*. In this case, the surface is weaker than it was; which I prove evidently, because it is now but able to raise 28 of Mercury. Imagine next, the said surface to have raised the Mercury two inches above *FG*, then it follows, that it must be yet weaker, because it's now but able to raise 27 inches: for by supporting two ounce of the *Pondus*, it loseth two degrees of it's own *Potentia*. In raising three inches of Mercury, it is three degrees weaker; and in raising four, it is four degrees weaker, and so forth; therefore, having raised 28 inches, there is but one degree of force remaining in the surface. And when it hath raised the whole, namely 29, it is no more able, and can no more press. For confirmation, put the case that the surface of Air *FG*, were as able, and had as much Pressure in it, after it hath raised 29 inches of Mercury, as it is after the raising of 10; then it follows of necessity, that after the raising of 20, it shall raise 19 moe, which is impossible; seeing the greatest altitude is 29. It follows of necessity, (I say) because after the raising of 10, it is able to raise 19 moe: therefore if it be as able after 20, as after 10, it must raise 19 after 20. Yea, if it be as able after 20 as 10, it must be as

able after 29 as 10. If this be, then it may raise other 29, and a third 29, and so *in infinitum*. Therefore, I conclude, that when two Fluid Bodies are in *equilibrio* one with another; or when the *pondus* is equal to the *potentia*, none of them doth actually press upon another, at least the surface hath lost all its Power and Pressure, which is also evident in the Pillar. For understanding this, let us suppose A C B. (Figure 11.) to be a Pipe 58 inches long, and full of Mercury, and every inch of it to weigh one ounce. Now, when the orifice D is opened, there is here as great an inequality, between the *pondus* and the *potentia* of the surface of Air E B, on which it rests, as was between the surface F G, and the *pondus* of Mercury H G. For as F G had 29 degrees of power to raise G H, so the Pillar A B has 29 ounce of weight, to overcome the surface E B. And as the surface F G, became one degree weaker, by raising one inch of the Mercury H G, and two degrees weaker, by raising two inches, and so forward, till it lost all its Pressure; so the Pillar, by falling down one inch, loseth one ounce of the weight; by falling down two, it loseth two ounce, and so forward, till by falling down from A to C, it loseth all its Weight and Pressure.

But here occurreth a difficulty; for if the surface F G, hath lost all its Pressure, by raising the Mercury from G to H; and if the Pillar C B, hath lost all its Pressure, by falling down from A to C; it follows, that when a Pillar of a Fluid, and a surface of a Fluid are in equal termes, or brought to an *equipondium*, there is no Pressure in them at all. For answer, consider first, that in all counterpoises, there are necessarily two things, the *movens* and the *motum*, the thing that moves, and the thing that is moved. Secondly, you must consider the *motum*, to have a *pondus*

or



or weight in it, and the *movens* to have a *potentia*, or power, wherewith it moves that weight. Thirdly, that as the thing that moves, hath a power or force in it self, whereby it moves, so the thing that is moved hath a power or force in it self, whereby it resists the motion. Fourthly, that sometimes the resistance of the thing *moved*, may exceed the power of the *movens*, as when a Quarrier with a Leaver, endeavours to prize up a stone too heavy for him: or the power of the *movens*, may exceed the resistance of the *weight*; or both may be of equal power. Consider fifthly, that as the *pondus* of the thing moved, begins to grow more and more, so the power of the *movens* decreaseth proportionably; not absolutely, as heat is extinguished in Water by the cold Air, when it is removed from the Fire, but respectively. For example, when a man holds a balance in his hand, with six pound in the one scale, and but one pound in the other, if you add another pound, the weight grows more, and the power and force of the opposite scale grows less proportionably; not *absolutely*, for it still remains six pound, but *respectively*: that's to say, six pound is less in respect of four, than in respect of five; or the resistance of six pound is less, two counterpoising it, than being counterpoised by one. When a third is added, the weight grows yet more, and consequently the resistance of the opposite scale becomes yet less, till by adding the sixth and last pound, you augment and encrease the *pondus* to that same degree of strength, that the resistance of the opposite scale is of. From these considerations, I say, the surface of Air F G, hath not lost all its Pressure *absolutely*, by raising the Mercury from G to H, but only *respectively*, because it still retains 29 degrees of force in it self. I say *respectively*, because when the Mercury is raised.

raised ten inches, the power of the Air which is of 29 degrees of force, is less in respect of ten ounce, then in respect of five; or the power of 29 degrees of force is less, being counterpoised by ten ounce, than being counterpoised only by five. And when it is raised 20, it is yet less in this respect, than in respect of ten. And when it has raised the Mercury to the greatest altitude H, it may be said to have lost all its Pressure, seeing it is not able, by vertue of a counterpoise, to do any more. Even as six pound in this scale, may be said to have lost all its resistance and weight, by putting in the other scale, first one pound, next two pounds, and then three pound, till the last be put in, at which time it hath no more resistance. Though this be, yet it still remains six pound. Even so, the Air F G still remains of the same force and power, while it suspends the Mercury G H, that it was of before. Likewise, the Pillar A B, cannot be said to have lost all its pressure *absolutely*, by falling down from A to C, but only *respectively*, because the said Pillar C B, is still 29 ounce weight. I say *respectively*, because in falling down ten inches, or in losing ten ounce, the weight that's now but 48, is less, in respect of 29, than while it was 58. It is yet less, when it hath fallen down other ten, because being now but 38, it must be yet less in respect of 29, than 48. And when it hath fallen down to C 29, it may be said to have lost all its weight, because it can do no more, having *respectively* lost all its Pressure.

From what is said, we see a clear ground to distinguish in Fluids a *pondus* and a *potentia*. Secondly, that the *potentia* may sometimes exceed the *pondus*, and contrariwise the *pondus* may exceed the *potentia*. Thirdly, that inequality of weight, between the *pondus* and the *potentia*, is the

the cause of motion of Fluids. Fourthly, that the motion never ceaseth, till the *pondus* and the *potentia* become of equal force. This conclusion is not so universal as the rest, because the motion may sometimes cease, before this be. For example, when the Air is pressing Mercury up thorow a Tub shorter then 29 inches, the motion ends before there be a perfect counterpoise; for 28 or 15 inches of Mercury, can never counterballance the force and power of the Air. In such a case then, there is an unequal Pressure, the Air pressing the Mercury more, than the Mercury doth the Air.

### EXPERIMENT VIII.

Figure 12.

**T**AKE the Vessel A B C D, and fill it with Water, as high as H I. Take next a Cylinder of stone F G, and drowning the half of it among the Water, suspend it with a chord to the beam N O, with a ring at E. Now in this case, though the stone do not touch the bottom of the Vessel, yet the Water becomes heavier, than before. For discovering the true reason of this, I suppose first, the weight of the Water, before the stone be drowned, to be 40 pound. I suppose next, that after the stone is drowned, the said Water to weigh 50 pound. And lastly, the stone to weigh 60 pound. I say then, the Water must be 10 pound heavier than before, because it supports 10 pound of the stone. 'Tis certain the beam is less burdened by 10 pound than before. If this be, then surely the Water must sustain it. It were great temerity and rashness, to averr that neither the Beam, nor the Water sustains it, which

which is really to say, it is sustained by nothing. It cannot be said without ignorance, that 10 pound of the *stone* is evanished, and turned into a *Chimera*. If it be said, how can such a Fluid Body as Water, be able to support any part of the weight of the *stone*, that is such a heavy Body? I answer, there is here no difficulty, for if the imaginary surface K L, upon which the 10 pound of the *stone* rests, be able to sustain 10 pound of Water (I suppose the *stone* taken away, and the place of it filled with Water) then surely it must also be able to sustain 10 pound of the heaviest metal; being ten pound of Lead, or Gold, or Stone, is no heavier than 10 pound of Water. If some say, this rather seems to be the reason, why the Water becomes heavier, after the *stone* is drowned, because it possesseth the place of as much Water, as would weigh 10 pound; not (as was said) because the Water supports 10 pound of it. Therefore it may be judged, and thought, that if the space that the *stone* occupies, were filled with Air, or some light Body, without sensible weight, the Water would become heavier than before. For example, if in stead of the *stone*, there were placed a *bladder* full of wind, within the Water, and tied to the bottom with a string, that the surface might swell from H I to A B, the Water of the Vessel would become as much heavier than before, as is the bulk of Water, equal to the quantity of the *bladder*. Therefore, the Water becomes heavier, not because it supports any part of the *stone*, but because the *stone* occupies as much room and space, as would contain 10 pound of Water: for by this means the drowned *stone* raiseth the Water from H I to A B; and so the Cylinders A C, and B D, being higher, press with greater weight upon the bottom C D, even with as much more weight,

as if the space that the *stone* occupies were filled with VWater.

For answer to this, we shall make this following Experiment. Take the Vessel M P V X, and fill it with VWater to Q R. Next, take a large *bladder* W Y full of wind, and tying the neck with a threed, thrust it below the Water, and fasten it to the bottom, with a string, to the Ring Z. This done, the Water swells, and rises from Q R, to M P. Now, if it be true, that the Water in the Vessel becomes heavier, not because it supports 10 pound weight of the *stone*, but because the *stone* occupies the room of 10 pound of Water, then it ought to follow, that after the *bladder* is tyed below the Water, the said Water should become heavier, than before, even by three pound, for I suppose a bulk of Water, equal to the bulk of the *bladder*, to weigh as much. And the reason is, because (as you say) the quantity of the *bladder* W Y, makes the water swell from Q R to M P, by which means the Pillars of Water M V, and P X becomes higher, and so presseth with greater weight upon the bottom V X. For clearing this difficulty, I say, when a *bladder* is thus below the VWater, tyed to the bottom, the VWater becomes not three pound heavier: for when you place the Vessel with the VWater and *bladder*, in the Scale of a Ballance, the said VWater weighs no more, than if it wanted the *bladder*: therefore the VWater becomes not heavier, because the *stone* possesseth the room of 10 pound of Water, but because the Water sustains 10 pound of the *stone*. Now the reason, why the *bladder* makes not the water heavier, though it raise it from Q R to M P, is this, because though verily there be a greater Pressure then before, even upon the bottom of the Vessel, yet because moe parts are not added,

the natural weight cannot be augmented, which essentially depends upon the addition of these parts. If it be replied, the Experiment of the *bladder* is to no purpose, because it being knit to the bottom, pulls up the Vessel, with as great force, as the growth of the Pressure bears it down, and so the *bladder* cannot make the Water heavier. But, if so be, it were possible, that the *bladder* could remain within the middle of the Water, without being knit to the bottom, and consequently without pulling up the Vessel, then surely the Pillars of Water *M V*, and *P X*, being higher, would press with greater weight upon the bottom, and so make the Vessel, and the Water weigh more in the balance: for 'tis to be supposed, that during all this time, this Vessel with the Water, is in one scale, and a great weight of stone or lead, in the other. So would the Water *A B C D* become heavier likewise, provided the space and room, that the stone fills among the Water, remained intire, after the stone is taken away: because that room and empty space remaining, would keep the surface, as high as *A B*, by which means, the Pillars *A C* and *B D*, being higher, would press with greater weight upon the bottom, and cause the Water weigh more in the balance. I answer, though by some extraordinary power, the *bladder* could remain below the water, of its own accord, as it were, and though the space and room, by that same power, which is left by the stone, were kept empty, yet shall they never be able to make the Water heavier. As to the reason, that's brought, I answer, the rising and swelling of the Pillars, will make indeed a greater Pressure upon the bottom of the Vessel, but because this Pressure may be produced, and generated without the addition of new parts, therefore, it can never make the Water heavier: for if this

were



were true, then it would follow, that the more a body is compress'd, it should be the heavier, which is contrary to sense, and experience. This Pressure is like unto *Bensil*, that cannot weigh in a ballance, though the *thing-bended* do weigh; as a Bow that weighs so many pounds, but the *Bensil* of it weighs nothing: Next, will any man think, that a Cub of Water six foot high, and six foot thick, will weigh more in a ballance, then it did, after it is turned into a long Square Pillar 216 inches high? I grant, there is near 60 times a greater Pressure, upon the bottom of the Vessel, yet because this Pressure is generated, without the addition of new parts, it cannot make the Water heavier. Moreover, it is *mechanically* possible to keep the VVater ST V X, under that same degree of Pressure it hath, though the rest above were taken away: if this be, then it ought to be as heavy, as the whole, seeing it still Presses the bottom, with that same degree of Pressure, it had from the whole: but what is more absurd, than to say, one part of VVater, is as heavy, as the whole? e. g. a pint as heavy as a gallon. If it be said, the Pressure, and the weight, are but one thing, at least *effectively*, which is sufficient to the purpose in hand, as is clear from the Theorem. 23. Answer, they are but one thing indeed, in order to the *Ballance of Nature*, but they are neither *formally*, nor *effectively*, the same thing in order to the *Libra* or *Artificial Ballances*, whereof we are now treating. I shall conclude with this; while the Vessel with the VVater, is thus placed in the Scale of the Ballance, and in *equilibrio*, with the opposite Scale, cut the string that tyes the bladder to the bottom, and when it comes above, you will find the VVater, just of the same weight it was of: for though the surface M P by taking out the bladder, settle down, to Q R, yet there's

no alteration made in the weight. From this I gather, that if the swelling of the VVater should make it heavier, then the subsiding and falling down of it, ought to make it lighter.

From these Experiments we gather first, that in VVater there is a Pressure, because it sustains 10 pound of the stone FG. Secondly, that whatever heavy body is weighed in Water, it loseth just as much of its weight, as the bulk of Water weighs, it puts out of its place. This is evident, because the stone is 10 pound lighter in VVater, than in the Air, because the VVater that would fill the room of the stone, is just of that weight. VVe see thirdly, that the Pressure of VVater, and the natural weight of it, are two things really distinct; because the Pressure may be augmented, without any increment of the natural weight. VVe see fourthly, that the Pressure, or *Bensil* of a Fluid, cannot affect the Scale of a Ballance, but only the natural weight. VVe see fifthly, that a body naturally heavier than Water, weighs in Water, because the stone FG, makes the Water about it, 10 pound heavier. If it be inquired, whether bodies, that are naturally lighter, will weigh in Water? I answer, if they be of any sensible weight, they weigh, as well as the other. For this cause, I except Air. For though they were never so light, in respect of Water, yet if they have any considerable gravity with them, they will make the Water heavier, they are among. Put the case the Body were a Cube of Timber of six inches, weighing sixteen ounces, and that a Cube of Water of that quantity, weighed 112 ounces. Here's a great inequality, between their natural weights: yet if that piece of Timber, were made to exist in the middle of Water, as the Bladder doth, it would make it 16 ounces heavier.

The

The reason is this, these 16 ounces are either supported by a surface of Water, or they support themselves. This last is impossible. If the V Water support them, then must they make the said V Water 16 ounces heavier. Note, that though a Body naturally lighter then V Water, as *Cork*, may be said to *weigh in Water*, that's to say, to make it heavier, in which sense V Water *weighs in Water*, because if you add a pint to a gallon, it makes it heavier, yet if you take a piece of *Cork*, and knit it to the Scale of a Ballance, by a threed, the *Cork* hanging among the V Water, the Scale hanging above in the Air, it will not *weigh in Water*; because in this sense, no Body *weighs in Water*, but that which is naturally heavier then V Water, as Lead, or Stone. In this sense, V Water doth not *weigh in Water*, as will be seen in the 17 Experiment.

## EXPERIMENT IX.

Figure 13.

Take a Glass-pipe 70 inches long or there-about, and of any wideneſs, having the upper end H, *hermetically* sealed, the lower end C compleatly open, and fill it with Mercury, and cause a *Diver* carry it down to the ground of the sea M N; where I suppose is standing the Vessel A B D E with stagnant Mercury, and drown the end below the surface A B. This being done, the Mercury falls from the upper end H, to the point G, and there halts; the space H G being empty. For understanding this Experiment, I shall propose several questions, and answer them. First, what's the reason, why the Mercury subsides, and sinks down from H to G? I answer, as formerly

merly in the like cases, inequality of weight between the *Pondus* of the impending *Quick-silver*, and the *Potentia* of the surface, of the stagnant *Quick-silver* D C E. For while the Tub is compleatly full, the weight is so great, that the surface D C E, is not able to sustain it, therefore it must fall down, seing motion necessarily followes in Fluids, upon inequality of weight. It may be inquired secondly, why it halts at G, 58 inches from A B, and comes no further down? I answer it halts at G, because when it hath fallen down to that point, there happens equality of weight, between the suspended Pillar, and the fore-said surface: for whatever weight the said Pillar is of, the surface on which it rests, is of the same. In a word, the *Pondus* of the one, and the *Potentia* of the other are now equal. For understanding this, consider according to the 25 Theorem, that the weight of the Element of Air, upon the surfaces of waters, is equivalent to the burden of 34 foot of water, therefore the first and visible surface of this Water L I K, is really as much prest, with the burden of the *Atmosphere*, as if it had 34 foot of Water upon it. Consider next, that between the said surface, and the ground M N, are 34 foot of Water indeed. Consider thirdly, that a Pillar of Water 34 foot high, is exactly of the same weight, with a Pillar of Mercury 29 inches high, for if Water be 14 times lighter than Mercury, then they cannot be of equal weight, unless the one be 14 times higher than the other. Now, supposing the weight of the Air upon the surface L I K, to be equivalent to 34 foot of Water, or (which is the same thing) to 29 inches of Mercury, the surface of the stagnant Mercury A B, must be as much burdened with the incumbent Water, and the Air together, as if it had really resting upon it, a Pillar of Mercury

Mercury 58 inches high. If this be, then it follows by necessity, that there must be an equality of weight, between the *pondus* of the Mercury in the Tub, and the *potentia* of the surface D C E, Or (which is all one thing) that the part C, on which the Pillar rests, is no more burdened, than the part D or E. For if 34 foot of Water, and 34 foot of VVater, be equivalent for weight, to 58 inches of Mercury, then must the part D and E, be as much burdened with the said weight, as the part C is burdened with the Pillar within the Tub, seing both are of the same height: therefore the power, and force of the imaginary surface of the stagnant Mercury D C E, is of the same strength, with the weight of the Pillar G F B. And this lets us see the reason, why the whole 70 inches cannot be suspended; for if the outward Pressure that's upon A B, be but equivalent to the Pressure of 58, it can never make the surface D C E able to support 70.

To make it evident (if any doubt) that the Mercury is suspended by the weight of the Water, and the weight of the Air superadded, let a *Diver* bring up this Engine to the top of the Water, and he will find the one half to have fallen down, namely from G to F, the other half F B remaining. And if it were possible, to convey this Experiment to the top of the Air, the Bearer would see, the remaining half to fall down likewise, and become level with A B; for where no Pressure of Air is, there can be no Mercury suspended. This falling down, is not all at once, but by degrees, and keeps a proportion with the Pressure of the Air, that grows less and less, from the ground to the top.

From this Experiment we see first, the great Pressure and weight, the Elements of Air and Water are under, seing

feing this Water, that's but 34 foot deep, sustains the Mercury between G and F, 29 inches; as much between F and E, being kept up by the Pressure of the Air. We see secondly, that this Pressure is according to *Arithmetical Progression*, as 1, 2, 3, 4, 5. because in going down the first 14 inches, the Mercury rises one inch; in going down the second 14 inches, it rises two; in going down the third 14 inches, it rises three, and so forward. We see thirdly, though a VVater were 100 fathom deep, yea 1000, yet the Pressure of the Air above is found at the bottom: for supposing this Experiment were 100 fathom deep, yet would the Air from above have influence upon it, to sustain so many inches of the Mercurial Cylinder. A *Diver* then, 10 or 15 fathom under the VVater, must be burdened with the weight of the Air, as well as with the weight of the VVater, so must the Fishes, though never so deep. We see fourthly, that the parts of a Fluid cannot cease from motion, so long as there is an inequality of weight between the *pondus* and the *potentia*. This is clear from the falling down of the Mercury from H to G. And as soon as equality of weight happens, the motion ends. This is clear from the Mercurie's halting at G. Fifthly, that in Mercury, as well as in Water, or Air, surfaces may be distinguished, and that these surfaces, are endowed with a *Potentia* or power, begotten in them by superior and extrinsick weight. This is clear from the imaginary surface D C E, that's made powerful to support 58 inches of Mercury in the Tub, and that by the weight and Pressure of the Air resting upon A B. Sixthly, that, as two Fluids differ in *specifick* and natural weight, so they differ in *altitude*, when they counterpoise one another. This is clear from the disproportion that's between the altitude



itude of the Mercury suspended, and the height of the Water, and Air suspending. G F then is 29 inches, and the deepness of the Water from K to N is 34 foot, because Water is naturally 14 times lighter than Mercury. F B is likewise 29 inches, and the height of the Air, that rests upon the surface of Water is *six* or seven thousand fathom high; because Air is 14000 times *naturally* lighter than Mercury. Seventhly, that Fluid Bodies counterpoise one another, not according to their *thickness* and *breadth*, but only according to their *altitude*. This is evident; for though this Tub were never so wide or narrow, yet the altitude of the Mercury is unchangeable. Hence it is, that the *thickest* Pillar of Water in the Ocean, is not able to suspend more Mercury, than the *slenderest*, I mean as to altitude. And hence it is, that the smallest Cylinder of Mercury, no thicker than a silk thread, is able to counterpoise a Pillar of Water, of any thickness whatsoever. We may conclude lastly, that when a *Diver* is 20 fathom under the Water, he is under as much burden, as if he were under 14 or 15 foot of Quick-silver. Suppose a man lying on his belly, within a large Vessel, and 14 or 15 foot of Mercury poured in upon him, surely it may be thought, that such a burden were insupportable. But put the case, the *Diver* were down 40 fathom, then must the burden be doubled. This follows, because if a Pillar of Water 34 foot high, with the weight of the Air superadded, be as heavy, as 58 inches of Mercury, then surely a Pillar 20 fathom high, or 100 foot, must be as heavy as 170 inches, which is more than 14 foot.

## EXPERIMENT X.

Figure 14.

**A** Gainst the former Experiment, there occurs some difficulties, which must be answered. As first, if it be the Pressure of the Water, that sustains the Mercury in the Tub (see the 13. Figure) then the weight of the said Mercury ought not to be found, while the Tub is poised between a mans Fingers. But so it is, that when a *Diver* grips the Tub about the middle, and raises it a little from the bottom of the Vessel, he not only finds the weight of the Tub it self, but the weight also of the 58 inches of Mercury that's within it. But this ought not to be, if the said Mercury, be sustained by the outward Water. In a word, it ought not to be found, because the said Pillar of Mercury, as really stands, and rests upon the imaginary surface D C E, as a Cylinder of Brass or Stone, rests upon a plain Table of Timber or Stone. If then, it be supported by the said surface, why ought I to find the weight of it, when I lift up the Pipe a little from the bottom of the Vessel? For clearing this difficulty, consider, that when the Mercury falls down from H to G, it leaves a sort of *vacuity* behind it, wherein there is neither Air nor Water. Consider secondly, that for this cause, there happens an unequal Pressure; the top of the Tub without, being burdened with the Pillar of Water I H, which actually presseth it down, and nothing within between G and H, that may counterballance that downward Pressure. These things being considered, I answer to the difficulty and say, it is not the weight of the suspended Mercury that I find, but the weight of the Pillar of Water I H, that rests up-

on

on the top of the Tub. If it be said, the Pressure of a Fluid is *insensible*, and cannot be found. I answer, it's true, when the Pressure is equal and uniform, but not when the Pressure is unequal, as here. If it be asked, how comes it to pass, that the Pillar of Water I H, is exactly the weight of the 58 inches of Mercury? I answer, besides the said Pillar, there is another of Air, that rests upon the top of it, which two together are exactly the weight of the suspended Mercury; I H being of the same weight with the Mercury G F, and the foresaid Pillar of Air, being of the same weight with the Mercury F B. To make it more evident, remember that one inch of Mercury, is exactly the weight of 14 inches of Water; and that one inch of Mercury, is of the same weight with 14000 inches of Air. If this be, then must the Pillar of Water I H, that's 34 foot high, and of the same thickness with the 29 inches of Mercury G F, be of the same weight with it, seeing 29 inches are to be found 14 times in 34 foot. For the same reason, is the Pillar of Air, namely S I, that rests upon the top of the Pillar of Water I H, of the same weight with the 29 inches of Mercury F B. For after a just reckoning, you will find, that 29 inches will be found 14000 times in the Pillar of Air, that rests upon the Pillar I H. Or in a word, the height of the Air is 14000 times, 29 inches.

But here occurs another difficulty. Let us suppose there were a Tub six foot high, one inch wide, having the sides, 3 inches thick. Imagine likewise the said Tub to be under the water 34 foot, with 58 inches of Mercury in it, as is represented in this 14 Figure. This being supposed, the Pillar of Water E A F C G D, must be far heavier, than the 58 inches of Mercury H B. The reason is clear,

because the said Pillar, is not only 34 foot high, but as thick, as the Diameter of the Tub, whose sides are three inches thick. I answer, the whole weight of that Water  $E A F C G D$  is not found, while a man poises the Tub between his fingers, but only the weight of the part  $G A$ , which is exactly the weight of the Mercury  $H B$ . But here occurs the great question, namely, why I find only the weight of the Water  $G A$ , and nothing of the weight of the Water,  $C E$ ; or  $D F$ ? I answer, I cannot find the Pressure of the Water  $C E$ , because it is counterpoised with the upward Pressure of the Water  $I K$ . And for the same reason, I cannot find the weight of the Water  $D F$ , because it is counterpoised by  $L M$ ; but because there is nothing between  $H$  and  $A$ , to counterpoise the downward Pressure of the Water  $G A$ , therefore I find that. If it be objected, that the Water  $I K$ , cannot counterpoise the Water  $C E$ , because the one is farther down than the other, and consequently under a greater Pressure, than the other. I answer, though  $I K$  be stronger than  $C E$ , yet a compensation is made by the weight of the Tub. For understanding this, let us suppose the Water  $C E$ , and  $D F$ , to press downward with the weight of six pound, and the Water  $K I$ , and  $L M$ , to press upward with the weight of ten pound, there being four pound in difference. Suppose next, the Tub to weigh in the Air ten pound, and in the Water only six pound. If this be, then according to the eighth Experiment, and eighteenth Theorem, four pound weight of the Tub must rest upon the surface  $I L$ . And if this be, then must the Water  $I K$ , and  $L M$ , be four pound weaker with the Tub, than without it, and must only have six pound of upward Pressure.

From

From these Experiments we conclude first, the truth of the tenth Theorem, namely that the weight of a Fluid is only found by sense, when the Pressure is not uniform, and equal. This is evident from our finding the weight of the Pillar of Water I H, as in the 13 Figure. We conclude secondly, that in all Fluids, there is a *pondus* and a *potentia*; as is clear from the *pondus* of Water E A F C G D, that presseth down the Tub, and the *potentia* of the Water I K L M, that presseth up the same Tub. We see thirdly, that there cannot be two surfaces of Water differing in altitude, but they must differ in degrees of Pressure: because the surface E A F, is weaker, than the surface I L, that being higher than this. We see fourthly, that two surfaces differing in strength, may be made equal by some Body or other interveening; because, though I L be stronger than E A F, yet seing it supports four pound of the Tub, it presseth up with no more force, than E A F, presseth down with. We see fifthly, that a Body suspended in a Fluid, as in Air, or in V V ater, may have one part of it prest equally with that Fluid, and another part unequally: this is evident, because the parts E and F, are equally prest with the Pillars C E, and D F, seing this Pressure is counterpoised with the Pressure of V V ater, I K, and L M. But the middle part of the Tub A, is unequally prest, seing it is prest downward, with the V V ater G A, but not prest upward with the Mercury B H. V V e see sixthly, that whatever be the thickness of a Pillar of a Fluid; yet no more of its weight is found, or is sensible, than the part, which presseth unequally: for though E A F C G D, be a Pillar six or seven inches thick, yet no more of the Pressure is sensible, than what comes from  
G A.

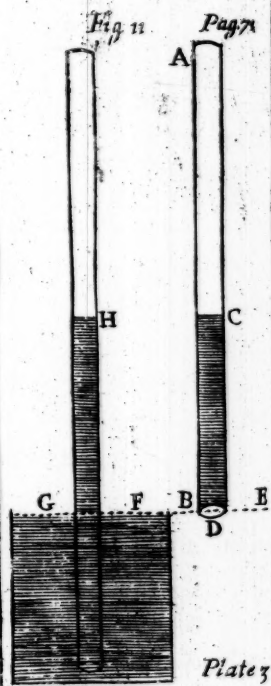
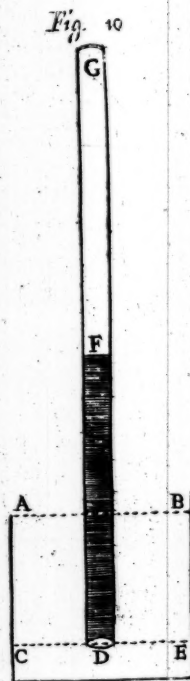
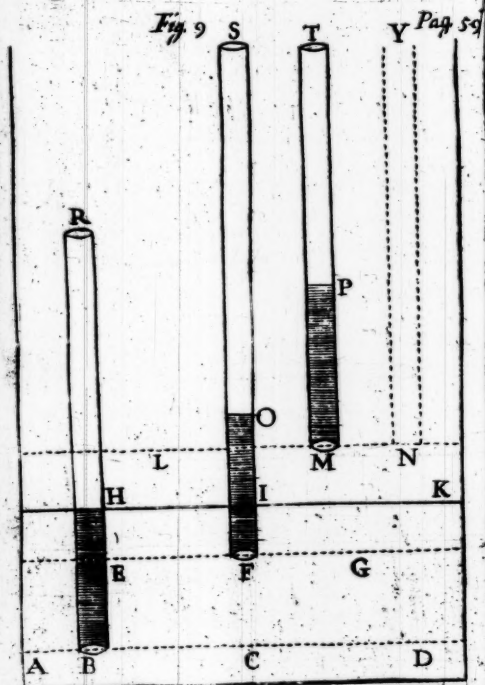




Fig 13

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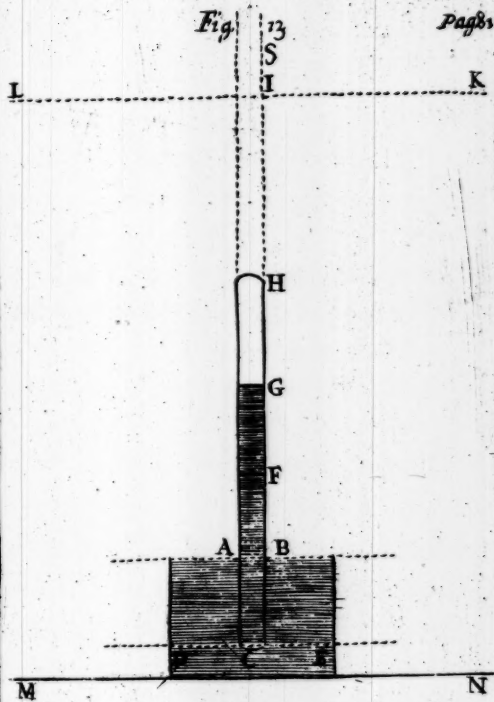
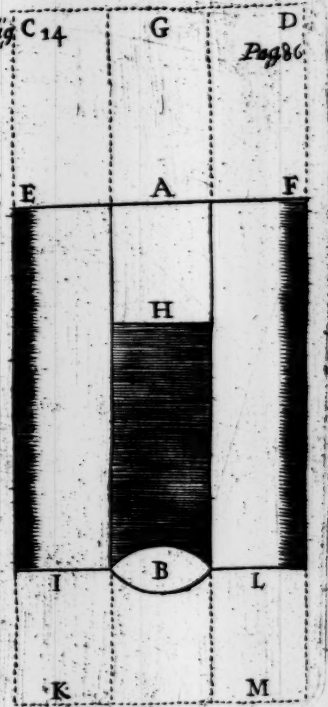


Fig C 14

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G A. VVe see seventhly, that a Body equally prest with a Fluid, weighs less, but a Body unequally prest, weighs none at all. This is clear in many particulars; for a Stone weighed in VWater, loseth not all the weight, but a part, because it is equally pressed. But a Body unequally prest, as is the Mercury H B, hath no weight at all, as it now stands. For understanding this, you must consider, that the whole weight of it rests upon the surface of VWater I L. Therefore though it could be weighed by a string, passing from the top H, to a Ballance existing in the Air; yet the said Ballance would find none of its weight, seeing it is wholly suspended by the VWater; but a Stone so weighed, is only suspended in part, by the Water.

## EXPERIMENT XI.

Figure 15.

**A** M Z C is a Water 15 foot deep. A B a Glasstub 14 inches long, and full of Mercury. B C a Pillar of Water 13 foot, 10 inches high, thorow whose middle goes a string to the scale of the Ballance K, existing in the Air. D E is a Tub full of Mercury 28 inches long, with a Pillar of Water above it E F, 12 foot and eight inches. G H a Tub 42 inches long, with a Pillar of Water above it H I, 11 foot and six inches high. And lastly, A D G S M an imaginary surface, 15 foot deep. This Experiment is brought hither, to demonstrate that a heavy Body, weighs as much in Water, as in Air, which is point-blank to the common received opinion, and destructive of the 18 Theorem. To evince this, I must suppose the 14 inches

inches of Mercury in the Tub A B to weigh 14 ounce; and the 28 inches of Mercury D E, to weigh 28 ounce; the 42 inches G H to weigh (I mean in the Air) 42 ounce. Now I say, to make a just *equipondium* between the two Scales K and L, there must be 14 ounce put into the Scale L. If after this manner you weigh the Tub and Mercury D E, 28 ounces will be required in the Scale L, and 42, if you weigh the Tub and Mercury G H. For proving this Doctrine, I must appeal to Experience, which will not fail in this. If you reply, and say, upon supposition the Tub and Mercury G H, were a solid piece of brass, or iron thus suspended in the Water, ought it not to weigh less here than in the Air, even as much less, as is the weight of the quantity of Water, it puts out of its place: why then should not the Pipe H G, with the Mercury in it, do the same, seeing there is no apparent difference between them, as to this?

But to leave this, which will appear afterwards, and to let the Reader see the truth of the 18 Theorem, I affirm, 'tis not the weight of the 14 ounces of Mercury A B, that burdens the scale of the Ballance K, and that makes a counterpoise with the 14 ounces of Stone, or Lead, that is in the scale L. What then is it, you say? I answer, 'tis 14 ounces of the Pillar of Water B C that does this. Neither doth the weight of the 28 ounces of Mercury D E burden the Ballance, but only 28 ounces of the Water E F. Neither doth the Ballance support the weight of the 42 ounces of Mercury G H, but it is only burdened with 42 ounces of the Water H I. The reason is most evident, because according to the Principles of the *Hydrostaticks* already laid down, the Cylinder of Mercury A B, within the Tub A B, rests immediatly upon the imaginary surface

face of the Water A D G, and therefore cannot burden the scale in any wise. The same is true of the other two Cylinders of Mercury. But in this I find small difficulty. The greater is, how to make it out, that the scale K, supports 14 ounces of the Water B C, and 28 of the Water E F, and 42 of the Water H I. To make this seem probable, consider first, as was noted, that this VWater is 15 foot deep, and consequently the Pillar of VWater B C, 13 foot 10 inches. The VWater E F 12 foot eight inches. And H I, 11 foot and a half. Consider secondly, though this be true, yet we must count the Pillar of VWater Z M 49 foot high. The reason is evident, because the Pressure of the Air, upon the surface of all Waters (according to the 25 Theorem) is equivalent to 34 foot of Water: this then being added to 15, makes 49, and by this reckoning the Water B C is 47 foot ten inches: the Water E F 46 foot eight inches: And lastly, the Water H I 45 foot six inches. Thirdly, for easie counting, I must suppose the whole Cylinder Z M to weigh 42 ounces, every 14 inches one ounce: and consequently the Water B C to weigh 41 ounces, the Water E F to weigh 40 ounces, the Water H I 39 ounces. Note, that in *Physical* demonstrations, 'tis not needful to use *Mathematical* strictness in counting; and so leaving out fractions, we shall onely use round numbers. Consider fourthly, that in all Fluids, as hath been frequently marked, there is a *pondus* and *potentia*, the Water B C being the *pondus*, and the Mercury A B the *potentia*, the one striving to press down the Tub, the other striving to press it up. Consider fifthly, that by how much the more a Body suspended in a Fluid is pressed up, by so much the less the weight that presseth it down is found: and contrariwise,

trariwise, by how much the less it is pressed up, by so much the more the Pressure above is found. Consider sixthly, the less that a surface of Water is burdened, the more able it is to counterballance the opposite Pressure, and the more it is burdened, it is the less able. Consider seventhly, that the Mercury AB, ( which is evident in all Fluids ) not only presseth downward, and burdens the surface ADG, but also presseth upward, and therefore actually endeavours to thrust up the Tub; and so it is, that the Tub is pressed between two, namely between the Water CB, and the Mercury within it.

Now from these considerations I say, the scale K, must support, and bear up 14 ounce of the Water BC: for seeing the Mercury is supported by the surface of VWater on which it rests, it cannot by any means burden the ballance with its weight; and seeing it actually presseth up the Tub, ( according to the seventh consideration ) it must so much the more counterpoise ( according to the sixth ) the opposite Pressure of the VWater BC, and consequently diminish the weight of it: so that the Ballance cannot support the whole, but a part. For according to what degrees of force, the Mercury presseth up the Tub with, according to the same, must the Pressure upon the top of the Tub be diminished, and so if the Mercury press up the Tub with the force of 27 ounce, the VWater BC must press it down with 14 ounce only, and so the Cylinder BC, that weighs really 41 ounce, must press the top of this Tub only with 14, which 14 ounce really counterpoiseth, the 14 ounce of Stone in the Scale L. But how is it made out, that the Mercury AB, presseth up with 27 ounce? For understanding this, remember, that the VWater is 49 foot high, taking in the Pressure of the Air, and that a

Water of that deepness is able to support 41 inches of Mercury, every inch weighing one ounce. For if 14 of Water, be able to support one of Mercury, 49 foot, or 567 inches, must support 41. If then, the part of the surface A, be able to weigh 41, it must have of upward Pressure 27 ounces, seing it's counterpoised *de facto* only with 14. Take notice, that in the *Hydrostaticks*, the word *pressing*, or *weighing*, as really and truly signifies a weighing up, as a weighing down, seing it is no less essential to Fluid Bodies to move upward, than downward, and that with equal force, and weight. According to this reasoning, the Ballance supports 28 ounces of the Water E F, (Imagine the second Tub to be suspended as the first) seing the Cylinder of Mercury D E, presseth up the Tub only with the weight of 12 ounce, which 28 ounce, really counterpoiseth the 28 ounce of Stone in the Scale L. But why doth the Mercury A B press up with 27 ounce, and the Mercury D E with 12? For answer, remember, (according to the sixth consideration) the shorter a Cylinder of Mercury is, the surface upon which it rests, is the stronger, and more able to press it up; and contrariwise, the longer it is, the surface is the more unable and weak: therefore A B being shorter, and lighter than D E, the surface of Water must press it up with greater force: so that if the said surface A M, be able to press up the Mercury A B with 27 ounce, it must press up the Mercury D E only with 12 ounce. According to this rule, if the Mercury A B were 15 inches high, it would press up only with 26 ounce, if it were 16, with 25: if 17, with 24: if 18, with 23, and so forward. This leads us to a clear discovery of all the secrets here: for if the Mercury A B, thrust up the Pipe, with the weight of 27 ounce, then must



must the Scale K, be eased of so much weight, and so much must be subtracted from L. Now let us imagine the Pipe A B, to be empty both of Air, Water, and Mercury: in this case 41 ounce must be in the Scale L, to counterpoise it, seing the whole Cylinder B C, that weighs so much, does now really counterpoise it. Let us imagine next, these 14 inches of Mercury to rise, and fill the Tub A B: in this case, there happens a great alteration, because the rising of them, are really equivalent to the subtracting of 27 ounce from the Scale L; and the reason is, because by so rising and filling the Tub, they thrust up the said Tub, and by this means easeth the Scale K, of so much weight. Now this Scale being eased, you must of necessity take out from L 27 ounce for making a new counterpoise.

And lastly, the Scale K must support the whole weight of the Water H I, which is 39 ounce, nothing remaining to counterballance this downward Pressure, and consequently to ease the Ballance. How then is it counterpoised? For clearing this, you must remember that this Water, that's really 15 foot deep, must be reckoned (as I said) 49, because of the Pressure of the Air upon the top, that's equivalent to 34. If then it be so, it cannot raise Mercury higher in a Tub than 42 inches; the one being 14 times heavier than the other: so that if 14 inches of Water, cannot raise Mercury higher than one inch, 49 foot cannot raise it higher, than 42 inches: for as 14 inches, are to one inch; so is 49 foot to three foot and an half, which is 42 inches. Now I say, the whole weight of the Water H I, rests upon the top of the Tub, and so presseth down the Scale K, to which you must imagine this Tub, knit by a string, as the former was, nothing remaining to

counterpoise this downward Pressure: for the top of the Mercurial Cylinder being raised as high within the Pipe, as the surface of Water D G S, is able to raise it, the said top can impress no force upon the Tub within, to thrust it up, and so to ease the Scale K. For example, when a man erects upon his hand a Cylinder of Timber, or any such like thing, which is the outmost he can support, he will not be able to impress any impulse, upon the ceiling of a room above his head; but if so be, in stead of that raken away, there be one lighter erected, which he is able to command, he can easily thrust up the ceiling at his pleasure. Just so it is here; for the 42 inches of Mercury, being the outmost, that the surface of Water D G S is able to bear, it cannot impress any impulse therewith upon the top of the Tub within: but easily can the Cylinder D E impress an impulse, and more easily the Cylinder A B, seeing they are lighter, and so more powerful. To evidence this a little more, let us imagine two things, first, the Tub G H to be empty, as if *vacuity* were in it. In this case the top of the Tub ought to bear the whole burden of the Water, and consequently the Ballance to bear it also: because there is not a *potentia* within the Tub, to counterpoise this *pondus*. Next, let us imagine the Tub to be only full of Water: according to this supposition, the Ballance cannot be in the least part burdened, because the Water within the Pipe, presseth it up with as much force, as the Water I H presseth it down: and if any thing should burden the Ballance, it would be only the weight of the Pipe, that's not considerable.

From what is demonstrated, we see first, that though this Experiment would seem to prove at the first, that a heavy Body weighs as much in the Water, as it doth in the Air,

Air, because the whole weight of the Mercury A B is found in the scale L, yet 'tis not so, because the 14 ounce of Stone L, doth not counterpoise any of the Mercury A B, but 14 ounce of the Pillar of Water B C. Secondly, there's here a clear ground, for asserting a *pondus* and a *potentia* in Fluids; because this Tub A B, is prest down with the VVater B C, and prest up with the Mercury within it. Thirdly, there's here a clear ground for asserting the Pressure of VVater, even in its own place; because the Water B C, counterpoises by it's weight, the 14 ounce of Stone L. Fourthly, we see an excellent way for finding the weight of any Cylinder of Water; for whatever be the weight of the Mercury in the Tub, the Cylinder of Water, that rests upon the top, will be of the same weight exactly; this is evident in comparing the weight of the Mercury G H, with the weight of the Water H I. Fifthly, that whatever be the height, and weight of a Pillar of Water, yet the Ballance can sustain no more of it, than the just weight of the Mercury: this is also evident, because the scale of the Ballance, supports no more of the weight of the Water B C, than the just weight of the Mercury A B. We see sixthly, the further down a Pipe with Mercury goes through Water, the greater is the Pressure it makes upon the top of the Tub within: for put the case, this were 100 foot deep, the Mercury G H, that wants all upward Pressure now, would prest up the Tub with 40 ounce: the Mercury D E with 55, and the Mercury A B with 70. We see seventhly, the shorter a Cylinder of Mercury be, it is the stronger in pressing; and longer it be, it is the weaker; for there's more strength in A B, than in D E. We see eighthly, that the strength decays, and grows, according to *Arithmetical progression*, as 1, 2, 3, 4; because

if you make the Cylinder G H 41, that's now 42, it presseth up with one ounce. Make it 40 inches, it will press up with two ounces of weight. Make it 39, it presseth up with three. And contrariwise, make the Cylinder D E 29 inches, that's now but 28, it will press up with 11 ounce only. (VVith 28 it, presseth up with 12.) Make it 30 inches high, it will press up with 10. If it be 31 inches, it presseth up with nine, and so forward. Lastly, make the Cylinder A B 15 inches, that's now but 14, it presseth up with 26 (with 14, it presseth up with 27) make it 16, it presseth up with 25; make it 17, it presseth up with 24. We see ninthly, that in Fluids, we may make a distinction between a *sustentation*, and an *equipondium*. 'Tis evident here, because there's a perfect *equipondium* between the 42 inches of Mercury G H, and the outward Water that's 49 foot deep. But 'tis not so, between the said Water, and the Mercury D E, because the said Water is able to raise the said Mercury 14 inches higher: therefore the Water only *sustains* the Mercury D E, but *counterballances* the Mercury G H. We see tenthly, that the *pondus* of the pillar of Water B C is counterpoised by two distinct *powers* really. The one is the 14 ounce of Stone in the scale L, the other is the 14 inches of Mercury A B, that as really thrusts up the Water, as the scale K, pulls it up, by vertue of the opposite weight. Eleventhly, take away the Stone L, and you will find the Pipe with the Mercury A B sink down: this happens, not because the surface of Water on which it rests is not able to sustain it, but because the 14 ounce of the Water B C, that was supported by the Stone, doth now press it down. Twelfthly, the more a Body is unequally pressed by a Fluid, the more of the weight of that Fluid is sensible; and the more

more equally a Body is pressed, the less sensible is the weight of that Fluid: this is evident, because there's a greater weight of the VVater H I found in the Ballance (it takes 42 ounce to counterpoise it) than of the VVater E F, which is counterpoised with 28 ounce: and the reason is, because the top of the Tub H, supports the whole 39 ounce of VVater H I, the Mercury within the Tub, not being able in the least to counterpoise it, or thrust it up. But because the Tub D E, is more equally pressed (the VVater E F presseth down with 40, and the Mercury D E presseth up with 12) therefore less weight of the VVater E F burdens the Ballance, only 28 ounce. Hence it is, that because the Tub A B, is more equally pressed, than either D E or G H, there's less of the weight of the VVater B C, found in the Ballance, only 14 ounce. Thirteenthly, if in the instant of time, while the Tubs are thus suspended in the VVater, the Pressure of the Air above were taken away, and *annihilated*; then first, the 42 inches of Mercury G H would fall down, to about 13 inches. Secondly, the 28 inches of Mercury D E, would fall down to as many. And lastly; the 14 A B, would sink down to the same height. The reason is, because the Pressure of the Air being equivalent to 34 foot of VVater, no more would remain but 15 foot, which is the real height, according to Z M. But 15 foot of Water, cannot sustain more inches of Mercury than about 13. And consequently, first, 14 ounce of Stone in the Ballance, would counterpoise the whole Water B C. The reason is, because the Water B C is but of 14 ounce, and the Mercury A B, being but 13 inches high, could impress no impulse upon the top of the Tub within, that's 14 inches high. Secondly, 13 ounce of Stone in the Scale L, would coun-

counterpoise the whole Water E F, seeing E F is but 13 ounce. Thirdly, the same weight (one ounce being deduced) would counterpoise the Water H I, because in this case, it weighs but 12 ounce,

To proceed a little further, imagine the Pipe G H to be suspended by the ballance, as the Pipe A B is; and then a little hole opened in the top H, to suffer the Water to come in, till the Mercury subside 14 inches, namely from Q to O ( imagine this Tub to be the other ) and then stop it. The reason why the VWater rusheth in, and presserth down the Mercury, is the force and Pressure of it: for the said VWater, finding the Cylinder in *equilibrio* with the outward VWater, presently by its own weight, casts the scales, which is easily done, seeing the surface G S M supports as much burden as it can. But that which is more considerable is this; after the subsiding of the Mercury from Q to O; the *equilibrium* that was between the scale of the ballance, and the VWater Q R is destroyed: for whereas 42 ounces were required before; 29 will now do it. For understanding the reason of this, consider that between Q and O, are 14 inches of VWater rushed in, which are equivalent to one inch of Mercury. Next, according to former reasonings, the ballance must support 29 ounces of the VWater Q R; because in this case, the top of the Pipe within, is pressed up with the weight of 13 ounces; which in effect, diminisheth as much of the downward Pressure of the VWater R Q, which before had the burden of 39 ounces. But why is the Tub prest up with 13 ounces? I answer, because the Mercury, that before was 42 inches, is now but 28, or having the 14 inches of Water Q O above it, it is 29, therefore being shorter, the surface G S M is the more able to Press it up, even with as much more force, as it is in inches shorter.

In



In the second place, let in as much Water more, as will depress the Mercury other 14 inches, namely from O to P. In this case, 16 ounce of stone will make an *equipondium*; because, the 14 inches of Mercury P S, and the 28 inches of Water P O Q, being a far lighter burden by 26, than the 42 inches of Mercury, the surface G S M must be far able to press them up now, than before: and therefore, must diminish as much of the downward Pressure of the VVater Q R, that burdens the Ballance, as themselves wants of weight: seeing then, the whole Cylinder of Mercury, and Water together, are but equivalent for weight to 16 inches of Mercury, the top of the Tub within, must be prest up with 26 ounce; and therefore they by their upward Pressure, must diminish 26 ounce of the weight of the Water R Q, that weighs 39. Lastly, let in so much VVater, as will depress the last 14 inches P S; and you will find no more weight required in the Ballance to make an *equipondium*, than counterpoiseth the simple weight of the Tub, which is not considerable. The reason is, because, the part S, of the surface G S M, being liberated of the burden of Mercury, and sustaining only the VVater within the Tub, instead of it, this surface presseth up the VVater within the Tub, and consequently the top of it, with as great force, and weight, as the top of the Tub without is depressed, with the outward VVater R Q: therefore, 39 ounce depressing the Tub, and 39 ounce pressing it up, the Ballance must be freed of the whole weight of VVater R Q. If it be objected, that the 42 inches of VVater Q S, are equivalent in weight to three inches of Mercury; therefore the part of the surface S, being burdened with this, cannot press up, with as great force, as the VVater R Q presseth down. For answer, consider, that the part S, is able to

N

support

support 42 ounce of VVater, and next, that the VVater R Q weighs but 39. Then I say, being the 42 inches of VVater within the Tub, weighs only three ounce, the part S, that's burdened therewith, being able to support 42, it must press up with the weight of 39; and so counterbalance the VVater R Q.

If it be inquired, whether or not, would the 14 inches of Mercury A B fall down, a small hole being made in the top of the Tub at B: I answer, they would. If it be objected, that these 14 inches of Mercury, are not in *equilibrio*, with the Pressure of the ambient Water, as the Mercury GH, and therefore they cannot be so easily depressed by the Water, that comes in at the said hole. I answer, they must all fall down, and as easily, as the other, and that because of inequality of weight between the *Potentia* of the surface of VVater, and the *Pondus*. It's certain, the part A of the surface, cannot support more weight of any kind, than 42 ounce; but when a hole is opened in B, and the VVater comes in, 'tis then burdened with the weight of 14 ounce of Mercury, and with the weight of 41 ounce of VVater; so much the VVater B C weighs, which is 55 ounce: but a surface that hath only the *Potentia* of 42, can never support a *Pondus* of 55, no not of 43.

It may be objected thus: Put the case a Cylinder of Gold, or Brass were suspended in this VVater, as the Pipe and Mercury G H are suspended by the Ballance, would not the Ballance support the whole weight of it, without supporting any part of the weight of the VVater I H, that rests upon the top of it. I answer, there's a great difference between the two; because a Cylinder of Gold or Brass, suffers both the upward and downward Pressure of the VVater; but the Mercury G H, suffers only

only the upward Pressure, being freed of the downward, by the top of the Tub. From this Experiment of letting in the V Water upon the top of the Mercury, we see first, that when two Fluids are in *equilibrium*, one with another, a very small weight will cast and turn the Scales, because, if the sixth part of an inch of V Water come in at Q, it presently alters the height of the Mercury from 42 inches to less. Secondly, 'tis impossible for a surface of Water, to support more weight, than its own proper burden, because the part S, cannot support more, no not a grain, than 42 ounce of V We see thirdly, that it is as impossible for a surface of V Water, to support less, than its own burden, because whatever loss of weight the Pillar of Mercury S Q suffers, by the ingress of the V Water Q O, its made up again by the same V Water. If it be objected, that the 14 inches of V Water Q O, are not so heavy by far, as the 14 inches of Mercury, that fell down. I answer, its true; yet the part S, is as much burdened as before, because what is wanting in weight, its made up, and compensated by Pressure. We see fourthly, that the Pressure of a Fluid is a thing really distinct from the *natural weight*, according to the 22 Theorem; because though the 14 inches of Water Q O, are not so heavy naturally as the 14 inches of Mercury that fell down, yet the Pressure of them upon the surface S, is as much. We see fifthly, that 14 inches of Water, that is a body fourteen times lighter than Mercury, may have as much weight with them, as 14 ounce of Mercury. We see sixthly, that a Cylinder of Mercury cannot be suspended in Air, or in Water unless it be guarded with a Tub, to preserve it from the downward Pressure of that Air or Water; for by opening an hole in Q, the Mercury subsides. We see seventhly, that 'tis impossible for two Fluids to suspend

one another mutually, unless there be a sort of *equipondium* between them; because no sooner you destroy the *equipondium*, between the 42 inches of Mercury Q S, and the part of the surface S, by the ingress of the Water Q O, but as soon there ariseth a new one. We see eighthly (as we noted before) the nearer a Body comes to be equally pressed with a Fluid, the less is the Pressure of that Fluid *sensible*: because less weight is required in the Ballance, to counterpoise the Pressure, and weight of the Water R Q, after the ingress of the Water Q O P, than after the ingress of the Water Q O. We see ninthly, that when a Body is equally, and uniformly pressed with a Fluid, the Pressure is *insensible*: because, after the Water hath thrust down all the Mercury from Q to S, there's no more weight at all of the Water R Q found in the Ballance. We see tenthly, that not only in Water, the Pressure of Water may be found; but out of it, namely in the Air, as is clear from the Ballance, that supports the Pressure of the Water R Q. We see eleventhly, a ground to distinguish between the *natural Ballance*, and the *artificial Ballance*. The *artificial Ballance*, is the Ballance K L: the *natural*, is the Pipe Q S. We see twelfthly, that they keep a correspondence between themselves, or some *Analogy*: for by what proportion the Water thrusts down the Mercury, by that same proportion the *pondus* L, of the Ballance is lessened: and by what proportion the Mercury rises in the Pipe, by that same, is the weight L augmented in the Scale. We may subjoyn lastly, that the easiest way of explicating the *Phenomena* of Nature, is not always the best, and truest. For some may think, it were far easier to say, that the Ballance supports the Mercury A B, or D E, and not any part of the Water B C, or E F. But such a way would be false, and absurd, and contrary to all the former Doctrine. E X,

## EXPERIMENT XII.

Figure 16.

**T**His Schematism represents a Water 100 foot deep, whose first and visible surface is I H K. And L M is the ground of it. C D is a piece of *brass* 30 inches high, and 12 inches in diameter, suspended upon the imaginary surface of Water A N B, which is distant from the top I H K, 25 foot. This *Brass* cannot go farther down, when demitted from H; because it's kept up, by the Force and Pressure of the surface of Water A N B, which I prove thus. The part B sustains *de facto*, a Pillar of Water K B 1400 pound weight: therefore the part N is able to sustain as much. I suppose here, the said piece of *Brass* to weigh 1400 pound. The Water K B is 1400 pound, because it's a Pillar 25 foot high, and 12 inches thick, for one cubical foot weighs 56 pound *Trois*. The connexion of the argument is evident, because it is as easie for a surface of Water, to sustain a solid Body, as to sustain a Fluid Body: therefore, if the part B, support the Fluid Pillar K B, the part N must be able to support likewise the solid Pillar C D, which is of the same weight. If it be objected, that the part N, sustains besides the *Brass* C D, a Pillar of Water E F 22 foot high, and a half, which two will weigh 2260 pound. I answer, upon supposition, that neither Water nor Air succeeded, the space E F being void of both, the *Brass* would be suspended with the force and power of the Water N. And though this cannot be made *practicable*, yet the *Theory* of it may conduce much for explicating the secrets and mysteries of the *Hydrostaticks*. But why ought the *Brass* to be suspended

pended at 25 foot from the top? I answer, because the *potentia* of the surface A N B, is equal to the *pondus* of the *Brass*. To evidence this, consider that *Brass* is a Body naturally heavier then Water, I shall suppose ten times, that's to say, one inch of *Brass* will counterpoise ten inches of Water. If this inequality be, then must this Pillar of *Brass* go so much farther down, than the first surface I H K, as the one is heavier *in specie*, or *naturally*, than the other: therefore it must sink 25 foot exactly; seing a piece of *Brass* 30 inches high, requires 400 inches of Water, or 25 foot to counterpoise it: for if one inch of *Brass* require ten inches of Water, then surely 30 inches must require 300. Yet it is no matter, what the thickness be, provided it be no higher than 30 inches.

To advance some farther, let us make a second supposition, namely, while the *Brass* is thus suspended upon the surface A N B, suppose the Air to come down, and fill up the imaginary space E F, then must the *Brass* be thrust down as far as the surface O P, that's 34 foot below the surface A N D, and 59 from the top. The reason of it is this, because the weight of the Air superadded, is equivalent to the Pressure of a Pillar of Mercury 29 inches high, and 12 inches thick: therefore the *Brass* being burdened with this, it must go so farther down, till it meet with a surface, whose *potentia* is equal in weight, to the *pondus* of both, which is precisely 59 foot from the top: for if one inch of Mercury require 14 of Water, then 29 inches must require 405 inches, or 34 foot. In a word, it must go as far down, as that surface, that sustains a Pillar of Water, that would counterpoise in a Ballance, the *Brass* C D, and a Pillar of Mercury 29 inches high, and 12 inches thick, both which weighs 3290 pound.

From



From what is said, we see first, that of two heavy bodies differing in weight, the lighter may go further down than the heavier. This is clear, because a slender *Cylinder of Gold*, in form of an Arrow, half an inch thick, and 28 inches long, weighing 28 pound ('tis no matter, though the just weight of it be not determined) will go down 35 foot in Water, before it meet with a surface, whose *potentia* is equal in weight to its own *pondus*; for if *Gold* be 15 times heavier *naturally* than Water, then the said Cylinder must go down before it rest, 420 inches, or 35 foot. But a piece of *Gold* 12 inches long, and six inches thick, that perhaps will weigh 208 pound, will sink no further than 15 foot. And the reason is, because, if one inch of *Gold* require 15 of Water to counterpoise it, then 12 must only require 180, or 15 foot. Note, that both the bodies must go down *Perpendicularly*, and not as it were *Horizontally*, with their sides downmost: for if they go down after this manner, they cannot sink so far. The reason of this is also evident, because a heavy body goes so far down, and no further, till it hath thrust as much Water out of its place, as will counterpoise it self in a Ballance. That's to say, if an heavy body weigh 100 pound, it must go no further down, than after it hath thrust out 100 pound of Water. But so it is, that a piece of *Gold*, in form of an Arrow, going down *side-wise*, or with the two ends parallel to the Horizon, will thrust as much Water out of its place, as will be the weight of it self, before it can go down 15 or 16 inches from the top: because for every inch it goes down *side-wise*, it expells 28 inches of Water. In going down two inches, it expells 56. In going down three inches, it expells 84, and so forward, till it go down 15 inches, where it expells 420 inches: but

but 420 inches amounts to 35 foot. Now, take a Cylinder of Water 35 foot high, and just the thickness of the Cylinder of Gold, which I supposed to be of half an inch, and put them in a ballance, and you will find the one just the weight of the other. Neither can the piece of Gold go so far down as before, if it go down *side-wise*, because for every six inches it is drowned, it expells a bulk of Water 12 inches long, and six inches thick; therefore it must be suspended, before it go beyond 90 inches, or seven foot and an half: now, if six inches give one foot, 90 inches will give 15 foot: but 15 of Water in height, and six inches thick, is the just weight of it in a ballance, *viz.* 208 pound. We see secondly, the broader and larger the surface of a Fluid be, 'tis the more able and strong to support an heavy burden: therefore the part of a surface of Water six inches square every way, will carry a far greater weight, than a part four inches square. Though a surface of Water 34 or 35 foot deep, be not able to sustain a Cylinder of Gold, if it exceed 28 or 29 inches in height, yet take a Cylinder of Gold, 10 foot high, and reduce it, by making it thicker, to the height of 20 inches, a surface of Water little more than 24 foot deep will sustain it. Or reduce a Cylinder 10 foot high, which requires a surface more than 100 foot deep, to a Cylinder six inches high, a surface little more than seven foot deep will support it. We see thirdly, the reason why bodies that are broad and large, move slower through Air and Water, than bodies that are more thin, and slender, though both be of the same weight in a ballance. For example, 20 pound of Lead, long and slender like an Arrow, will go sooner to the ground of a deep Water, than a piece of Lead of the same weight, in form of a Platter or Bason. The reason is, because as the body

is broader, so it takes a broader part of a surface, which broader part is stronger and abler, than a narrower part, and so makes the greater resistance. The same is the reason, why a Bullet six inches in Diameter, moves slower thorow the Air, shot from a Cannon, than a Bullet one inch in Diameter. For the same reason, Ships of seven or eight hundred Tun, move far slower thorow the Air, and Water, than Vessels of less burden. Item, large and big Fowls, as Eagles, move slower, than small Birds, as Swallows. Yea, of Fowls of the same quantity, one may move quicker than another, as is evident in long-wing'd Hawks, as *Falcons*, that by the sharpness of their Wings, move far more space in half an hour, than Kites, or Gold-Hawks, whose wings are rounder. We see fourthly, that there's nobody how heavy soever, but it may be supported by the surface of a Fluid, either in Air or in Water. I grant, the strongest surface of Air, that can be had, is not able to support more weight, than a Cylinder of Gold 28 inches high: yet though it were as large, and broad, as a *Mill-stone*, if it do not exceed the said height, the Air is able to sustain it. For the same cause, if it were possible to free a *Mill-stone* of the Air, that rests upon it, the Air below would lift it from the ground, and carry it up many fathoms, even till it came to a surface, equal in power to the weight of the Stone. Or, if a large *Mill-stone* were admitted from the top of the *Atmosphere*, towards the Earth, it could hardly touch the ground, being detained by the ways, by a surface counterpoising it. Or if it did touch, through the swiftness of the motion, it would surely, as it were, rebound, and be carried up again. It is alwayes to be remembred, that in such trials, the Air is supposed not to follow, or to be united, after the Stone passeth

passeth thorow. Now if the Air be able to do this, far  
 more the Water, that's a body a thousand times heavier.  
 We see fifthly the reason, why heavy bodies move so  
 easily thorow Air, and Water, namely because the parts  
 that were divided, by the body that is moved, are pre-  
 sently reunited, and closed again, by which means it is  
 driven forward, the Pressure upon the back, being as much  
 as the Pressure before. If this were not, no body what-  
 soever would be able to move it self one foot forward.  
 For example; if, when a man hath advanced one step for-  
 ward, the Air did not close again upon his back, the force  
 of the Air upon his belly and breast, would not only stop  
 him, but violently thrust him backward. We see sixthly,  
 the reason, why the same body descends with more diffi-  
 culty thorow Water, than Air, because a surface of Water  
 is far stronger, than a surface of Air. We see seventhly,  
 that a heavy body is never suspended by a surface of  
 Water, or Air, ingoing down, till once it hath displaced,  
 as much Water or Air, as will counterpoise it self in a bal-  
 lance. This is clear from the *Brass* C D, that goes al-  
 ways down, till it expell its own weight of Water. For  
 this cause, if a *Mill-stone* were demitted, or sent down  
 from the top of the Air, and never rested, till it came  
 within 40 fathom of the *Earth*, then so much Air, as is  
 expelled by the descent, is the just weight of the stone.  
 We see eighthly, the heavier a body be *naturally*, than Wa-  
 ter, it goes the further down, and the lighter it is, it sinks  
 the less. For if C D were of Gold, it would go fur-  
 ther down, than being of Brass or Iron: and if C D were  
 a stone, that's lighter *in specie* than Brass, it would not go  
 so far down. This lets us know the reason, why thicker,  
 blacker, and heavier clouds comes nearer to the *Earth*,  
 than

than thinner, whiter, and lighter, 10 We see ninthly, that the Pressure of the Air is determinable, even in its highest degree, and seemes to be the same in all places of the world; but the Pressure of the Water is not so. 11 The reason of the first part is, because the Element of Air seems to be of the same height in all places, and therefore we may know its outmost Pressure, which is just equivalent to the weight of 28 or 29 inches of Gold, or Mercury. But because the deepness of the Sea is variable, therefore the Pressure is variable likewise. 12 Yet if the exact deepness, of the deepest place were known, it woud be easie to determine the greatest Pressure of it, as to determine the greatest Pressure of the Air. 13 We see tenthly, that a very small weight added or subtracted in height, will change and alter the counterpoise of a Fluid. 14 Because if you lay but one ounce upon the top of the *brass* at *E*, it presently subsides accordingly; or take one ounce from it, and it rises. But though never so much weight be added to it, or subtracted from it in thickness, no alteration follows. 15 Therefore, though this piece of *Brass* *ACD*, that is now but 12 inches in thickness, were made 24, by which means the weight would be tripled and more; yet the same surface *ANB* would sustain it: yet, add to it in altitude, wth one inch, and presently it sinks down proportionably. 16 This evidently, discovers the reason, why it is as easie for the Air, to support a Cylinder of Mercury 3 inches thick, as to support a Cylinder half an inch thick: and why it cannot support more in height than 29 inches, and why it cannot support less. 17 Now the reason, why a thicker Pillar, is as easily suspended, as a thinner, is this, because if a Pillar of Mercury be thicker, and consequently heavier, it likewise takes a broader, and consequently a stronger surface of Air to rest upon:

upon: if it be but slender, and so but light; then it takes a lesser part of a surface to bear it up, and consequently a weaker; by which means the *Pondus* of the one, is alwayes proportionable to the *Potentia* of the other. Is it not as easie for a Pillar of Stone, 6 foot in Diameter, to support another six foot in Diameter, as it is for a Pillar one foot in Diameter, to support a Pillar one foot in Diameter? But as a Pillar one foot in Diameter, cannot support a Pillar 6 foot in Diameter; neither can a surface of Air, one inch in Diameter, support a Pillar of Mercury 6 inches in Diameter. But why should a larger part of a surface be stronger than a narrower part? I answer, the one is stronger than the other, for that same reason; why a thicker Cylinder is heavier than a thinner: for what I call *strength* in a surface, lies nothing else but *weight*, and what I call *weight* in a Cylinder, lies nothing else but *strength*. The same thing hath two names, because the pillar of a Fluid presseth down, and the surface supports: therefore, in the one its called *pondus*, in the other *potentia*. As when two scales are in *equilibrio*; either this, or that may be called the *pondus*; one either this, or that, may be called the *potentia*. Now I say, if a part of a surface four inches broad, have as much weight or force in it, as a Pillar of Mercury four inches thick; then surely, a part of a surface eight inches broad, must have as much weight and force in it, as a Pillar of Mercury eight inches thick. But why ought a surface to succumb; when the Pillar grows in height, and not to fail when it grows only in breadth? *Ans.* VVhen it grows in breadth, the *pondus* never exceeds the *potentia*; but when it becomes higher, then it becomes heavier. That's to say; when a Pillar grows broader, there's not one part of the surface that sustains it, more burdened than another;

seeing



seing the part eight inches broad, is no more prest with a Pillar eight inches thick, than the part four inches broad, is prest with a Pillar four inches thick: as eight ounce of Lead in this Scale, is no more counterpoised with eight ounce in the other Scale, than four ounce in this Scale, is counterpoised with four in the other. But when a Cylinder grows in-hight, the *pondus* exceeds the *potentia*; one part of a surface being more burdened than another. We see eleventhly, that in a large surface of a Fluid, wherein are many parts, each part is able to sustain its own proper burden. So a part eight inches in Diameter supports a Pillar eight inches thick; and a part four inches, supports a Cylinder four inches thick; but cannot support a Pillar six inches thick. But this seems rather to flow from the *disproportion* of *Magnitudes*, seing a circular plain 4 inches in diameter, cannot receive a Base of a Pillar 6 inches in diameter. But this is certain from the very nature of Fluids, that in a deep VVater, wherein may be distinguished 100, or 1000 different surfaces, each one is able to support his own burden, and no more.

### EXPERIMENT XIII.

Figure 17, 18, 19.

**F**OR making this Experiment, take two *plain* Bodies of Brass, or Marble well polished. Make them of any quantity; but for this present use, let each of them be four inches broad square-wise. Upon the back part, let each one have an handle about six inches long, of the same metal, formed with the *plain* it self, in the founding (if they be of Brass) as is represented in this Schematism, When they

they are thus prepared, anoint their inner-sides with Oyl or Water, and having thrust the one face alongst upon the other, with all the strength you have, till all the four edges agree, two whereof are represented by A B, and C D, you will find them cleave so close together, as if they were but one Body. The effect is this, that ordinary strength will not pull them asunder; and that under a surface of Water, a stronger pull is required than in the Air.

That we may deduce some *Hydrostatical* conclusions from this Experiment, let us suppose these two *plain* Bodies to be united in the middle of the VVater I K P Q, that's 34 foot deep, and suspended by a beam or long tree T V existing in the Air, near the top of the VVater, by a chord S E passing between the middle of the beam, and the end of the handle at E. Suppose next a great weight of Lead R, 350 pound, to be appended to the end of the handle at H, of the under *plain* Body C D N O. This done, I affirm, that the beam T V, neither sustains the under *plain* Body C D N O G H, nor the 350 pound weight of Lead R, that hangs down from the handle G H. If it be objected, that the beam supports the upper *plain* Body A B L M F E; therefore, it must bear the weight also of the under *plain* C D N O G H, with the weight R; seing they are both united together, and cleave so close, as if they were but one Body. I answer, it supports the one unquestionably, but not the other. To explicate this *Hydrostatical* Mystery, I must aver three things; first, that the inferior *plain* is supported by the upward Pressure of the lower VVater P Q N O. Secondly, that the burden which the beam sustains, is not the weight of the under *plain*, but the weight of the 34 foot of Water I K L M. Thirdly, that this weight is exactly the weight of

of the inferior *plain*, and Lead R. But is it not more easie to say, that the beam supports both the *plains*? I answer, if I say so, I can neither affirm truth, nor speak consequentially. But may it not be said, that the inferior *plain* is supported both by the beam, and the lower water PQNO? I answer, this is impossible, because one and the same weight, cannot be supported totally, by two distinct supporters.

For making these assertions evident, I must suppose the superior Water IKLM to be 34 foot deep, and to weigh, if it were put into a ballance, 400 pound; and which is unquestionable, that the said Water rests upon the back of the superior *plain* LM. I suppose secondly, that the lower Water PQNO weighs as much, and thrusts up the inferior *plain* with as great weight, as the superior *plain* is prest down with, by the superior Water. This is evident from former Experiments. And lastly, I suppose each *plain* to weigh two pound, and the weight of Lead R 350. It is to be observed here, that no mistake may arise in the calculation afterwards, that though it be said, this 34 foot of Water weighs 400 pound, yet in itself it weighs but 200; but considering the Pressure of the Air upon IK, which is as much, it may be truly said to weigh 400. These things being premittid, I say the weight that the beam TV sustains, is not the weight of the interior *plain*, and the Lead R, but 352 pound of the superior Water IKLM, and consequently, that the inferior *plain* is supported by the lower Water PQNO. The reason is, because the lower Water presseth up with the weight of 48 pound. It is in it self 400 pound: but being burdened with 352, it cannot thrust up with more weight than 48. Now, it pressing up with 48, must be the

the beam of 48, and counterpoise so much of the superior VWater, and consequently the beam must support only 352 pound of it. But put the case (you say) the weight R, were 130 pound, 160 pound, or 180 pound, would the beam be less or more burdened with the superior Water? I answer, if R be 130 pound, then the beam supports only 132 pound of the superior Water; for if the inferior be only burdened with 130, the weight of R, and with two the weight of the inferior *plain*, then must it press up with 368, and by this means, must ease the beam of so much, it sustaining 132 pound only. According to this computing, when the Lead R weighs 160 pound, the beam supports only 238 pound of the superior Water. If it weigh 180 pound, it sustains 218. And if the weight R were taken away, the beam supports no more of the superior VWater than two pound.

To proceed a little further, imagine the two *Plains* to be drawn up 17 foot nearer the first surface IK, namely as high as ZW. This done, the union breaks up, and they presently fall asunder. The reason is, because the surface ZW is not able to support 352 pound, but only 300, which I prove thus. If 68 foot sustain 400, then 51 foot must sustain 300. I say 68, and not 34, because as was noted, the Pressure of the Air upon the surface IK, is equivalent to other 34 foot: and therefore though the deepness of this VWater, between IK and LM be but 34 foot really, yet it is 68 foot virtually, and in effect. Imagine secondly the surface IK to subside 17 foot, namely to ZW. In this case the union is broken also, and the lower *Plain* falls from the upper. The reason of this, is either same with the former; because by what proportion you diminish the height of the superior VWater, by that same

same proportion you diminish the upward Pressure of the lower VVater. Therefore, if you subtra& from the superior VVater 17 foot, that weighs 100 pound, you subtra& likewise 100 pound from the inferior VVater, and consequently, you make it press up only with 300, but 300 is not able to counterpoise 352.

Let us suppose thirdly, the superior *Plain*, and the superior Water to be annihilated; then I say, the Pressure and force of the under Water would thrust up the inferior *Plain* and the weight R about eight foot higher then X Y and there suspend them. The reason is, because the surface X Y, being able to sustain 400, and being burdened only with 352, must have the weight of 48. Now the upper *Plain* being taken away, and the upper Water also, and the empty space of both remaining, the said weight of 48 pound, must carry the under *Plain* as high as is said. Let us suppose fourthly, the Pressure of the Element of Air, that rests upon I K, to be taken away, then must the two *Plain* bodies be disunited, the inferior falling from the superior. The reason is, because in this case, the superior Water would have but the weight of 200 pound, and consequently the inferior, would press up only with as much: but 200 is not able to counterpoise 352.

From what is said we see first, that in all Fluids there is an upward Pressure, as well as a downward; and that the one is alwayes of equal force to the other: because the inferior *Plain* is pressed up with as great force, as the superior *Plain* is pressed down with. We see secondly, that in Fluids, there is a *Pondus* and a *Potentia*. The *Potentia* here is the inferior Water, and the *Pondus* is the superior. Or, the 350 pound of Lead R, may be called the *Pondus*, which counterpoiseth the *Potentia* of the surface

of VVater X Y. We see thirdly, that though the Pressure of a Fluid, be not the same thing with the natural weight, yet it is equivalent to it: because the 352 pound of Lead R, is sustained by the Pressure of the inferior VVater, which could not be, unless they were virtually the same. We see fourthly, that there may be as much Pressure in one foot of Water, as there is weight in 100, or in 1000 foot, or in 1000 fathom. For put the case, these two plain bodies were suspended, 100 fathom below the surface of the sea; and within a foot or two of the ground, as much weight would be required to pull them asunder, as is the weight of a Pillar of Water 100 fathom high, and 4 inches thick every way, which will be more then 3000 pound weight; besides the weight of the Air above, that will weigh 200 pound. This could not be, unless there were as much Pressure in the lowest foot of this Water, that's 100 fathom deep, as there is weight in the whole Pillar above. We see fifthly, the more the *potentia* of a surface is burdened, the more sensible is the *pundus*: because the heavier you make the Lead R, that burdens the inferior Water, the more weight of the superior Water rests upon the Beam. We see sixthly, the more *unequally* a body is pressed, the more the Pressure is *sensible*. For understanding this, consider that the under-face of the superior *Plain*, is more and less pressed, according to the more and less weight the Lead R is of: for put the case, the inferior *Plain* were taken away, the face of the superior *Plain*, would be equally prest with the back of it. But when the inferior *Plain* is united to it, the Pressure of the Water is kept off, by which means the back is prest more than the face. Now, as the inferior *Plain* becomes heavier and heavier, by making the weight R more and more weighty,



weighty, the less and less is the face of the superior *Plain* prest up. Hence it is, that as this inequality of Pressure becomes greater and greater; so the weight of the superior Water, affects the Beam more and more. Or, if the superior *Plain* were a sensible body, as *Animals* are, it would find the back of it more and more burdened, according as the weight R, becomes heavier and heavier. We see seventhly, that Water weighs in Water: because all the weight the Beam supports, is the burden of the superior Water, and not the burden of the interior *Plain*, or of the weight R. It supports the weight also of the superior *Plain*, but this is not considerable. This is only to be understood, when the Pressure is unequal; for if the upper *Plain* were as much prest up, as it's prest down, the weight of the superior Water would not be found by the *Beam*. We see eighthly, that the higher a surface be, it is the weaker; and the lower it be, it is the stronger: because when the two plain bodies are pulled up, 17 foot, they fall asunder. We see ninthly, the vanity of the common opinion, that maintains two plain *bodies* to cleave close together for fear of *vacuity*; and that neither *Humane* nor *Angelick* strength is able to break this union, without the rupture and fracture of them both.

It may be enquired, upon supposition, that the inferior *plain* had four holes cut thorow the middle, square-wise, as A B C D in the 18 Figure; what *Phænomena* would follow: Before I answer, consider that this Figure represents the inner face of the Brass-plate C D N O<sub>3</sub> of the 17 Figure, which as was supposed, is four inches from side to side, and consequently contains 16 square inches. Now, imagine the under *plain* C D N O<sub>3</sub> while it is united to the uppermost, to have four square inches cutted out of it,

as A B C D. These things being rightly conceived, and understood, I say, when the said holes are cutted thorow the beam T V, that now sustains 350 pound, shall by this means, only sustain 250 pound. To make this evident, consider that the under *plain* (as was said) contains 16 square inches. Next, that the top of the inferior Water upon which the *plain* rests, contains as many, and that every inch of the Water weighs 25 pound, seing the whole, as was supposed before, weighs 400 pound. Now, I say, the beam must support only 250 pound of the Water I K L M, because, these holes being made, the top of the inferior Water comes through them, and preffeth up the face of the superior *plain* with 100 pound, and so easeth the beam of so much. I affirm next, that though the inferior Water N O P Q be in it self 400 pound, and consequently able to support the inferior *plain*, with the weight R, albeit they weighed so much, yet the said holes being cut out, it is not able to support more burden than 300. The reason is, because of 16 parts that did actually bear up before, there are only 12 now that sustains. And every one of these twelve, being but able to support 25 pound, it necessarily follows, that the greatest weight they are able to sustain, is 300 pound. I affirm thirdly, that if a fifth hole were cut through, the under *plain* would fall from the upper; because in this case, the inferior Water is not able to support 350 pound as before, seing of 16 parts, there are five wanting, and eleven remaining, cannot support more weight than 275 pound. More questions of this kind might be proposed; as first, what would come to pass, if the upper *plain* had as many holes cut through it, answering to the four of the nether? Secondly, what would follow, if the nether *plain* were intire, and four bored through the

the upper? But I shall supersede, and leave these to be gathered by the judicious Reader.

From this Experiment we see first, that the broader and larger a surface of a Fluid be, it's the more able to sustain a burden; and the narrower it be, 'tis the less able. Secondly, that each part of a surface, is able to sustain so much weight, and no more, and no less.

Before I put a close to this Experiment, it will be needful to answer an objection, proposed by *Doctor More* in his *Antidote against Atheism*, against the Pressure of the Air, which in effect militats, by parity of reason, against the Pressure of the Water likewise. He argues thus. If the Air were indowed with so much Pressure, as is commonly affirmed, then it ought to compress, squeeze, or strain together, any soft body that it environs, as, *v. g. Butter*. Put the case then, there were a piece of *Butter*, four inches broad every way, and one inch thick, containing 16 square inches, upon every side; as may be represented by the Figure 19. In this case, there is a far greater Pressure, upon the two faces, than upon the four edges; and therefore, it ought to be compressed, and strained together, to the thinness of a sheet of Paper. For answer, let us suppose the piece of *Butter*, to be 30 or 40 foot below the surface of a Water, where it ought to suffer far more Pressure, than above in the Air. Next, that it lies *Horizontal*, with one face upward, and the other downward. Thirdly, that the upper face supports a Pillar of Water 200 pound weight, and consequently, that the under face is prest up with as much. And lastly, that every edge is burdened with 50. It may be represented, with the help of the fancy, in the 19 Figure, where AB is a piece of *Butter* four inches square, and one inch thick. Only take notice,

notice, that nothing here is represented to the sight, save one of the four edges, namely *AB*; the other three, and the two faces being left to the fancy: Yet, the upper face may be represented by *FHKM*, and the under by *NOPQ*. These things being rightly understood, it is wondered, why the two great and heavy Pillars of Water, the one *EGILFHKM*, that presseth downward, and the other *NOPQRSTV*, that presseth upward, do not strain together the sides of the *Butter*; seeing the Pressure of the Water *BC*, and the Pressure of the Water *DA*, are far inferior to them for strength, even by as much difference, as four exceeds one. Though this objection seem somewhat, yet it is really nothing, which I make evident after this manner. First, I grant that the upper face *FHKM* is burdened, with 200 pound, and the nether face *NOPQ* with as much. Secondly, that the edge *B*, is only burdened, with 50 pound, as is the edge *A*. The other two edges, sustains each one, as much. Secondly, though this be, yet I affirm the two sides to be no more burdened, than the edges: that's to say, the Pressure upon the sides, is equal to the Pressure upon the edges, which I prove thus. The Pressure upon the part *M*, is equal to the Pressure upon the part *K*, but the Pressure upon the edge *B*, is equal to the Pressure upon the part *M*: therefore the Pressure upon *B*, is equal to the Pressure upon *K*. The major Proposition is evident, because the Pillar of Water *LM*, is of the same weight, with the Pillar of Water *IK*. The Minor is also evident, because, the Pillar *BC*, is of the same weight, with the Pillar *LM*. Now, if the Pressure upon the edge *B*, be equal to the Pressure upon *M* and *K*, it must be likewise equal to the Pressure upon *H* and *F*. If this be, then the  
edge

edge of the *Butter* B, must be no more prest, than the side F H K M: therefore the Water B C, can no more yeeld to the VWater E F G H I K L M, and suffer the *Butter* to be squeezed out at B, than the VWater L M, can yeeld to the VWater E F G H I K, and suffer the *Butter* to be squeezed out at M. If any man shall insift and say, that the upper face bears the weight of four Pillars, which weighs 400 pound; but the edge B is only burdened with 50: therefore 50 ought to yeeld to 400. I answer, according to the 29 Theorem, namely, that a *thicker* Pillar of a Fluid is not able to press, or move a *slenderer*, unless there be an unequal Pressure, therefore the thick Pillar, that presseth the face, cannot move the slender Pillar, that presseth the edge: but there is here no unequal Pressure, seing the Water X Y Z V, is of the same hight with the four Pillars that rests upon the face of the *Butter*. I grant, if the said Water were not so high, as the other is, by the one half; then surely the *Butter* would be squeezed out at B; because the shorter a Pillar be, the less Pressure is in the surface under it; therefore, there must be less Pressure, according to that supposition in the Water B C, then now is. Or put the case, the Pillar I K were shorter then G H, or L M, the same effect would follow, namely, a squeezing out of the *Butter* from K. Or, let us suppose the Pillar I K, to be higher than G H or L M. In such a case, the weight of the said Pillar would press through the *Butter*.

From what is said, we shall only infer this conclusion, that equality of hight between Pillars of a Fluid makes equal Pressure, and inequality of hight makes unequal Pressure. Therefore 'tis no matter, whether they be gross or small, thick or slender, provided they be all of the same Altitude.

Fig. 12

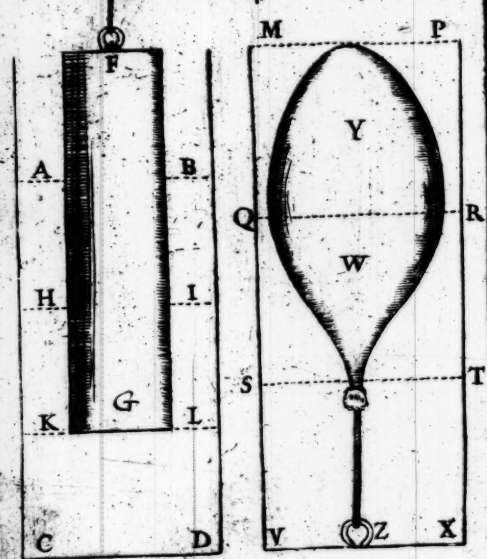


Fig. 13

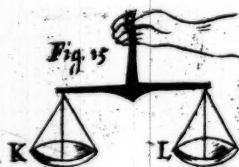


Fig. 14

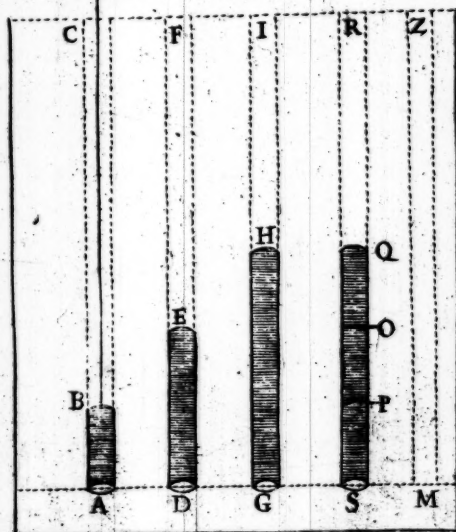
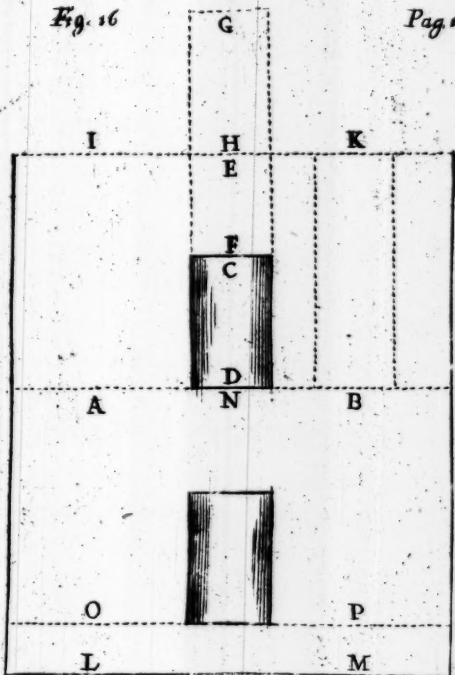




Fig. 16

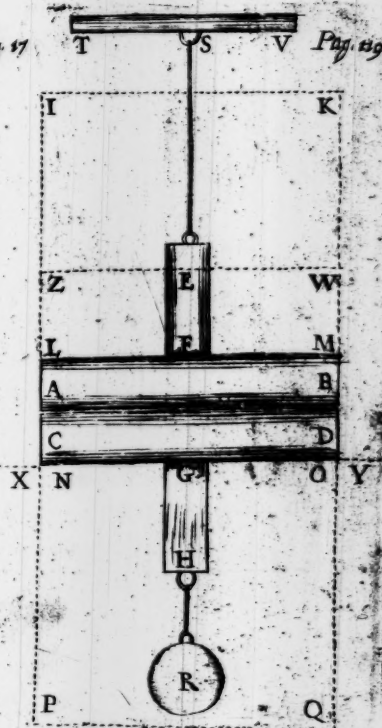
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Platt 4

Fig. 17

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## E X P E R I M E N T   X I V .

Figure 20.

**T**His Schematism represents a Vessel full of Water 8 foot deep. E F is a Glass-Pipe, open at both ends, about 9 foot high, and one inch in Diameter. A B C D is a Vessel of Glass, or of any other metal, thorow whose orifice above, the said Pipe comes down. B H I is a Pipe going out from the said Vessel, crooked with a right angle at H, that the orifice I may look upwards. That some *Hydrostatical* conclusions may be inferred from this Experiment, fill the lower Vessel A B C D with Quick-silver almost; then pour in as much Water above it, as will fill the space A B H, leaving from H to I full of Air. Next, thrust down the orifice of the Pipe E, below the said Water and Mercury, till it rest upon the bottom C D. Lastly, stop well with cement the passage of the lower Vessel, through which the Pipe came down, that neither Air nor Water may go out, or come in. These things being done, let down this *Engine* to the bottom of the large Vessel, which, as was noted, is full of Water from M N to K L, 8 foot, and you will find the Mercury to rise in the Pipe from A B to G, 6 inches, and more. The reason is, because there is a Pillar of Water K I, that enters the orifice I, and presseth down the Air, from I to P, 3 inches, which before was 6. This Air being so burdened, instantly presseth forward the Water H B A: and this pressing the surface of the stagnant Mercury A B, causes the liquor run up the Pipe from A B to G, 6 inches. The reason, why it riseth 6 inches, is this: between the surface of the stagnant Mercury A B, and the top of the water

Water L O K, are 84 inches. Now Water being 14 times *naturally* lighter then Mercury, there must be 14 inches of Water, required for sustaining one inch of Mercury, and consequently 84, for supporting 6. For a second trial, lift up the whole *Engine* to the top of the Water, and you will find the 6 inches of Mercury B G sink down, and become no higher within the Pipe, than the surface of the stagnant Mercury A B without. The reason is, because by coming up above the Water, the Pressure of the Water K I, is taken away from the orifice I, by which means the compressed Air H P, extending it self to I, liberats the Water A B H of the Pressure it had, and this freeth the Mercury of its Pressure, and so the 6 inches falls down. For a third trial, stop closely the orifice I, and let all down as before. In this case, you will find no ascent of Mercury from B to G: because the Water K I cannot have access to thrust down the Air from I to P, as formerly.

For a fourth, open the said orifice I, while the *Engine* is below the Water, and you will find the Mercury rise from B to G: because the Pillar of Water K I, hath now access to press. For a fifth trial, stop the orifice I, and bring up all to the top, and you will find the six inches of Mercury B G suspended, as if the *Engine* were under the Water. The reason is, because the stopping of the orifice, keeps the inclosed Air P H, under the same degree of Pressure it obtained from the Water K I. For a sixth proof, open the same orifice I, while the *Engine* is above the Water, and you will find the six inches of Mercury fall down, because the imprisoned Air H P, obtains now its liberty; and expanding it self from H to I, eases the Water B H of the burden it was under. For a seventh; pour in 14

inches

Q

inches of Water at the orifice F, till it rest upon the top of the Mercury at G, and you will find one inch fall down. Pour in as much, and two inches falls down. In a word, pour in as much Water, as will fill the Pipe to O, and you will find the whole six inches fall down. The reason is, because the Water K I, is not able to sustain, both the six inches of Mercury and the Water, that's poured in, any one of them being able and sufficient to counterpoise it. For an eighth trial, empty the Pipe of the said Water, and after the Mercury is ascended from A B to G, as formerly, suck out the whole Air between G and F, and you will find the Mercury to rise from G to R 29 inches. The reason of this is evident from the Pillar of Air S K, that rests upon the top of the Pillar of Water K I: for by sucking out the said Air, you take away the *pondus* or weight, that counterpoised the weight of the Pillar S K, therefore it finding its counterpoise removed, presently causeth the Water K I, to enter farther within the crooked Pipe, till it hath prest up the liquor to R. For a ninth trial, take the six inches of Mercury B G, and put them into the scale of a ballance; then take as much Water, as will fill the Tub between A B and O, and put it into the other scale, and you will find a most exact counterballance between them. The reason is, because if the Water K H, or a Pillar of that hight, be able to raise and counterpoise the Mercury B G, then must, as much Water, as fills the Pipe between B and O, be the just weight of it. The reason of this consequence is, because these two Waters are of the same weight: therefore, if the one be the just weight of it, the other must be so too. If it be said, that the Water, that fills the Pipe between B and O, is far thicker,

thicker, then the Water  $KH$ ; therefore they cannot be both of one weight. I answer, equality of *altitude*, in this *Ballance of Nature*, is equality of *weight*: therefore, seing the one Water, is as high as the other, they must be both of one weight. If it be said, that a Pillar of Water between  $K$  and  $H$ , cannot counterpoise the six inches of Mercury  $BG$ , both being put into a ballance: and the reason is, because the one is thicker than the other, I answer, this only proves that two Pillars differing in weight, in the *Libra* or *Artificial Ballance*, may be of one weight in the *Natural Ballance*: because in the *Artificial Ballance*, bodies counterpoise one another, according to all their dimensions; but in the *Natural Ballance*, such as this *Engine* is, Fluids counterpoise one another, according to their *altitude* only.

From the first trial, we conclude first, that Water even in its own place *gravitates* and *weighs*, because this Water by its Pressure, *de facto* thrusts up 6 inches of Mercury. We see in the next place, that the Pressure of a Fluid, is as easily communicated *Horizontally*, as *Perpendicularly*; because the Pressure runs alongst from  $H$  to  $B$ . We see thirdly, that Fluids, may have as much Pressure begotten in them, even while they are environed about closely with solid bodies; whereby the superior Pressure, immediately and directly by perpendicular lines is kepted off, as if they were immediately under the Pressure: because the Mercury  $ABCD$ , is as much burdened with the Pressure, that comes from  $H$ , as if the upper part of the Vessel  $AB$  were open to let in the superior Pressure, by perpendicular lines. The Air then under the roof of a House, is under as great a Benefit and Pressure, as the Air without, that's directly under the Pressure of the Atmosphere.

VVe see fourthly, that the Pressure of a Fluid, may be as easily communicated thorow the parts of *Heterogeneous* Fluids, as thorow the parts of *Homogeneous*; because the Pressure of the VVater K I, is as easily communicated thorow the Air P H, thorow the Water H B, and thorow the stagnant Mercury B D to the orifice E, as if nothing intervened but VVater. VVe see fifthly, that Mercury can suffer a Pressure, as well as VVater or Air; because the six inches cannot rise from B to G, unless the stagnant Mercury A B C D were compressed; even in all the parts of it.

From the second trial, we see, that there cannot be a *Pondus* in a Fluid, unless there be a *Potentia*, to counterpoise it: for when you take away the Water R I, by lifting up the Engine to the top of the Water, the Mercury B G presently falls down. From the third trial, we conclude, that the Pressure of a Fluid, cannot be communicated thorow solid Bodies: for when the Engine is drowned below the Water, with the orifice I, stopped, no ascent of Mercury follows. We conclude from the fourth trial, that it is impossible for two Fluids to counterpoise one another, unless they be in *Equilibrio*, because the Water K I cannot sustain the Mercury B G, unless it be of the same weight. From the fifth, we conclude, that a Fluid may be kept under the same degree of compression, after the superior weight that begat it, is taken away: for after the Engine is brought above the Water, with the orifice I stopped, the Mercury B G is still suspended, even by virtue of the Pressure, that's in the stagnant Mercury. This tells us, that a sphere of glass full of Air, may retain its *Densit*, even though the whole Element of Air, that begat it, were destroyed. From the  
sixth



sixth we gather, that a Fluid cannot abide under Pressure, when the burden is taken away that begat it, or that kept it under Pressure: for by opening the orifice I, the Air P H extends it self: and so are the VVater, and Mercury within the Vessel freed of their Pressure likewise. We gather from the seventh trial, that in the *Ballance of Nature*, one Scale cannot be more burdened then another; or that two *Fluids* cannot counterpoise one another, unless they be in *equilibrio*: for when you pour in 14 inches of Water, upon the top of the Mercury at G, they thrust down one inch, that there may be a just *equipondium*, between them, and the opposite weight K I. We gather from the eighth trial, which was observed before; first, that there cannot be a *Potentia* in a Fluid, unless there be a *Pondus* to counterpoise it: for when you suck out the Air G O, which was the *Pondus*, that counterpoised the Air S K, this presently in stead of it, raiseth 29 inches of Mercury from G to R. We see secondly, that one pillar of Air can counterpoise another; Fluids of diverse kinds interveening: because the Air S K, counterpoises the Air within the Pipe G O, the VVater K P first interveening; the Air P H next interveening, and the stagnant, and suspended Mercury interveening also. We see thirdly from this eighth trial, that the Pressure of the *Atmosphere*, may be communicated thorow diverse kinds of Fluids, without the least diminution of its weight: because the weight of the Pillar of Air S K, is communicated, and sent down thorow the Water K I, thorow the Air P H, thorow the VVater H B, thorow the stagnant Mercury B D, and up thorow the suspended Mercury B G, till it suspend the 29 inches between G and R, which is the just counterballance of it. We see moreover, that Fluids counterpoise

poise one another, according to *altitude* only, and not according to *thickness* and *breadth*; by comparing the Water K I, that's but half an inch thick, to the Mercury B G, that's a whole inch thick. We see from the last trial, that when a Fluid is necessitated, to counterpoise a Fluid of another kind, in stead of a Fluid of its own kind, it sustains no more of it, than what is the just weight of the Fluid of its own kind, because the VVater K I, being under a necessity to counterpoise the Mercury B G, in stead of so much VVater as would fill the Tub, it sustains no more of it, than the just weight of so much VVater, as is said. We see secondly, that when two Fluids of divers kinds, do counterpoise one another, that which is heaviest in *specie*, hath alwayes the shortest Cylinder. Next, that the difference between their altitudes, is most exactly according to the difference between their *natural* weights, therefore B G is 14 times lower than B O; because Mercury is 14 times heavier than VVater. We see moreover, that though two Cylinders of a Fluid, can counterpoise one another in the *Natural Ballance*, such as this *Engine* is, yet they will not do it in the *Artificial Ballance*: because though B G counterpoise K I in this Ballance, yet in a pair of Scales, the Mercury will be as heavy again as the VVater. We see lastly, that notwithstanding of this, yet such a thing may be; for if the orifice I, were made as wide as the orifice F, that the Cylinder K I might be equal to the Mercury B G in thickness, then surely the one would counterpoise the other in the *Libra* or *Artificial Ballance*.

## EXPERIMENT XV.

Figure 21.

**T**His Schematism represents a Water 72 foot deep, as C D A B, together with a crooked Pipe of glass I N H, the one half whereof is I P, 56 inches high, and one inch wide, the other half is P N R H, of a far narrower diameter, with an orifice H. There is also an orifice at L, with a neck, about which is knit a small chord M L, for letting down this *Engine* to the bottom of the V V ater A B. For trials cause, fill the wide glass with Mercury from P to K, and you will find it rise in the narrow Pipe, as high as the orifice H. This being done, close hermetically, or with good cement the orifice L; then by help of this chord, let all go down from the surface C D, till it be exactly 17 foot from the top, and you will find the Mercury thrust down in the narrow Pipe, from H to R, 14 inches and an half. Let it down next, as much, and the Mercury will be yet further thrust down, namely from R to N, the part H R N being full of Water. For understanding the reason of this, consider that between N and E, are 34 foot: for so high is the slender Pillar of Water, that comes from the top, and entring the orifice H, comes down thorow the Pipe to N. Consider next, that between the said Pillar of Water, and the Mercury N P K, there is a counterpoise: but this counterpoise cannot be, unless the Pillar of Water be 34 foot high, seing between N and K are 29 inches of Mercury; for each inch thereof requites 14 of Water. Upon this account it is, that when the glass is 17 foot drowned, 14 inches and an half are thrust down from H to R. If it be objected, that the *Pressure* and *Bensil* of the inclosed Air

I K,

IK, is equivalent to the weight of other 29 inches; and therefore the Pillar of Water E H R N, must be 68 foot high, before a counterpoise can happen. I answer, 'tis true that's said, but you do not consider, that there is a Pillar of Air F E, resting upon the top of the Pillar of Water, that makes a compensation exactly. To speak then truly and really, the 29 inches of Mercury N P K, have the weight of 58 inches; and the 34 foot of Water E H R N, have the weight of 68 foot.

For a third trial, let down the glass 6 foot further, and you will find the Water pierce up thorow the thick Cylinder of Mercury P K, and rest upon the top K. The only difficulty is to determine, how much will spring up before the motion of it cease? 'Tis evident, that the Water will ascend, because coming to the *Base* of a thick and gross Cylinder, that it cannot intirely lift, it must pierce thorow it, seeing the force of such a Pillar of Water, is now much stronger, than the Mercury: for in effect, the glass being drowned 6 foot further, the Pillar that comes down thorow the slender Pipe, hath the just weight of 34 inches of Mercury: but 29 cannot resist 34: therefore the Water not being able to lift it, by reason of the disproportion that's between the thickness of the one, and the slenderness of the other, it must pierce up thorow it. For clearing this difficulty, consider, that this glass cannot go down from one imaginary surface to another, *v. g.* from 34 foot, where it was, till it come to 40, where it now stands, but there must be an alteration in the *equipondium*, seeing by going down, the Pillar of Water E H R N grows higher, and consequently heavier; and therefore, some V Water must pierce up thorow the Mercury, for making a counterpoise; for 'tis impossible for two Fluids to counterpoise one another, unless

unless they be in *equilibrio*. Consider secondly, that after the Water is come to the top of the Mercury at K, it will find difficulty to find a room for it self, seing the space between S and I is full of Air. Notwithstanding of this, it must ascend. I say then, after the glass is gone down from 34, to 40 foot, there will be about four inches of VWater above K, which have reduced the 29 inches of Air K I, to 25, S I.

If it be asked, between what two things is the *equipondium* now? I answer, the first was at R, between E H R, and R N P K. The second was at R, between N R H E, and N P K. The third is now at S, between the 25 inches of inclosed Air I S, as one Antagonist, and the four inches of Water S K, with the 29 inches of Mercury K P, and the Water P N R H E, as the other. To make a fourth *equipondium*, sink the Glass other six foot, till it be 46 foot from the top C D, then must some more VWater spring up thorow the Mercury; this of necessity must be, seing the Cylinder of VWater N R H E, is six foot higher, and so far heavier, than it was: if this be, then must the 25 inches of Air I S, be reduced to less quantity; seing 'tis impossible, for one Fluid to become heavier, unless its opposite and *antagonist* become heavier too, for an *equipondiums* sake. Note, that the Air I S, will not lose other four inches, with this six foot of VWater, as it did with the former. The reason is, because, if for every six foot the Glass goeth down, the Air were comprest four inches, it were easie at last to reduce it to nothing; forbif six reduce it to four, and 12 to eight, 38 ought to reduce it to no inches, which is impossible. Therefore I judge it must suffer compression, by a certain proportion, as we see upon a Scale, the divisions of Artificial or Natural

*Sines* grow less and less, there being more space between 1 and 2, than between 2 and 3; more between 2 and 3, than between 3 and 4, and so upward till you come to 90. Therefore the second six foot, must reduce the 25 inches, not to 21, but to 23 *circiter*, and so forth. By the which means, though the Glass should go down *in infinitum*, yet the Air shall never be reduced to nothing, and there shall still some small quantity of VVater come up. Or in such a case, the Air may be so compressed, that it can be no more, all the *diffeminate vacuities* being expelled. But suppose this to be at 1000 fathom, then at 1500, where the Pressure is stronger, there can be no *equipondium*, which is absurd, for where the *pondus* becomes stronger, the *potentia* ought to grow stronger likewise. I answer, the motion of condensation ceaseth indeed; but there still remains a *potentia*, or rather in such a case, a perfect *resistentia*, whereby the Air is able to resist the greatest weight imaginable, before it can be reduced to nothing, or suffer a penetration of parts, that's to say, two parts to be in one space.

From the explication of these Phenomena we conclude first, that in Water there is a considerable Pressure, seeing in letting down the Glass 17 foot, the Mercury is prest down from H to R, and from R to N, in going down other 17 foot. Secondly, that 29 inches of Mercury are as heavy as 34 foot of VVater: because the Mercury K P N makes a just *equipondium* with the VVater E H R N. Thirdly, that Fluids not only of the same kind, but of different kinds, do counterpoise one another according to *altitude*, and not according to *thickness*; because though the Mercury K P N be far thicker, than the VVater E H, yet they counterballance one another, because a proportion is kept according to their *altitudes*. Fourthly, that a  
Fluid



Fluid *naturally* lighter, may move a Fluid *naturally* heavier, and thrust it out of its own place, because the Water coming in at H, thrusts down the Mercury to R, and from R to N, and so forth. Fifthly, that of two Fluids unequal in strength, debating together, the weaker of necessity must yeeld to the stronger, though the weaker be far heavier naturally than the stronger, as is evident in the Mercury, that yeelds to the Water. Sixthly, that it is impossible for two Fluids, so long as they are unequal in strength, to cease from motion, till they come to an *equilibrium*; because the Water alwayes springs up thorow the Mercury, till an equal Ballance happen. Seventhly, that one Fluid of this kind, can counterpoise another Fluid of the same kind, though there be divers Fluids interveening: because the Air F E, counterpoiseth the Air I K, or I S, notwithstanding of Water and Mercury interveening. Eighthly, that there may be as much Pressure in one inch of a Fluid, as in a million; because the 29 inches of Air I S, have as much *Benfil* in them, as is in the whole Pillar of Air E F, that goeth up from the top of the VVater, to the top of the *Atmosphere*. Ninthly, that when one Fluid is under Pressure, the next must be under the same degree of Pressure, though they be not of the same kind, but of different sorts; because the Air I S, the Water S K, and Mercury K P, are surely under the same degree of Pressure, otherwise the motion could not end. Tenthly, that when two Fluids of divers kinds do press one another, that which is *naturally* lighter, ascends alwayes to the higher place, and the heavier to the lowest: because the Air I S, is above the Water S K, and the Water S K is above the Mercury. Note, that this is not universal, but only happens when the lighter Cylinder, is slenderer than the other, for if the

Mercury K P, were no thicker than the Water P N R H, this would raise it intirely. Eleventhly, that the compression of Air to less space, is not according to *Arithmetical progression*, 1, 2, 3, 4, 5, but according to some other proportion, which may be called *Uniform-difform*. Note here, that though this be true of the Air, while it is compressed from a more quantity to a less, as here, or in a *Wind-Gun*; yet it is not true of the Pressure of the Element of Air, which is more and more from the top of the *Atmosphere* to the *Earth*, according to *Arithmetical Progression*, as in Water. We see lastly, that the heaviest of Fluids, such as Mercury, press upward, as well as downward; because the top of the Mercury K, thrusts up the Water K S, as well as it thrusts down the Water P N R H. It may be enquired here, how far this Glass would go down, before the 29 inches of Air I K were reduced to one inch? I answer, its hard to determine; but it seems it ought to go down more than 300 fathom. In this case, there would be 28 inches of Water above K. Let us suppose the orifice H to be stopped at that deepness, and the Glass brought above the Water; then, when the said orifice is opened in the Air, you will find the whole VVater P N R H thrust out: and not only this, but the whole Mercury P K, spring out at the orifice H likewise, except a little that remains between N and H: the reason is, because the 29 inches of Air, being reduced to one, would be under a very great *Bensil*; therefore the weight being taken away that begat it, of its own accord, it would expand it self to its old dimensions; which it could not do, unless both the 28 inches of VVater, that's supposed to be above K, and the Mercury K P were thrust out of their places.

EXPE-

## EXPERIMENT XVI.

Figure 22.

**T**His Schematisme represents a vessel full of Water 84 inches deep, namely from L N the first surface, to M R the bottom. From M to R in breadth are 20 inches. There are here also two Glass-Pipes open at both ends; the one, two inches wide, the other half an inch wide. Both of them are 85 inches long. X Y O is a surface of stagnant Mercury, among which the two ends of the Pipes are drowned. E C is a Pillar of Mercury six inches in height, and so is G D, both of them raised to that altitude, by the Pressure of the Water upon the surface X Y O. The Pillar E C A is supported by, and rests upon, the imaginary Pillar A P. And so is the Pillar G D B, supported by the Pillar B Q. There are three things that occurs here from this operation of nature to be enquired after. First, why ought the Mercury to rise in the two Tubs, after the Vessel is filled with Water? Secondly, why rather six inches, then seven or eight? Thirdly, what's the reason, why it rises as high in the wide Tub, as in the narrow? I answer, the Mercury rises from C to E, and from D to G, by the Pressure of the Water, that rests upon the surface X Y O. Before that the Water is poured into the Vessel, there is here a most equal and uniform Pressure upon the surface X Y O, both without and within the Tub, namely from the Air that rests upon it. But no sooner is the Water poured in, but as soon the Pressure becomes unequal; the parts of the surface without the Tub, being more burdened, then the parts C and D within. Therefore, the part that's less

less prest, must rise and climb up, till the Pressure become equal: for it's impossible that a Fluid can cease from motion, so long as there is inequality of weight between the *pondus* and the *potentia*. If any doubt, let him pierce the side of the Vessel, and when the whole Water is run out, he will find EC and GD to have fallen down, which clearly proves the climbing up of the Mercury, to depend upon the in-pouring of the Water. For understanding the reason of the second, remember that Mercury (as we have often noted) is counted 14 times heavier than Water; therefore EC must be six inches, being XYO is prest with the altitude of 84 inches of Water. It would be judged no marvel, to see the Mercury rise from C to E, and from D to G, provided the face of the stagnant Mercury were as high as ZF. No more strange it is, to see the two Mercuries rise, with the Pressure of the Water; for in effect and really, the said Water is the just weight of as much Mercury as would fill between XO and ZF. For understanding the third, remember (as was noted before) that Fluid Bodies counterpoise one another, only according to *altitude*: therefore 'tis no matter, whether the Tubs be wide or narrow. If it be enquired, how can one and the same Water, counterpoise two Fluids of different weights? To say, that Fluids counterpoise one another according to *altitude*, doth not clear the difficulty; for it still remains to be asked, why they counterpoise one another after this manner? Therefore it seems, that if the Water raise the Mercury from C to E in the wide Pipe, it must raise it in the narrow one from D to K. For answer, consider first, that as there are here two Pillars of Mercury CE, and DG within the two Tubs, so there are here also two Pillars of Mercury AP and BQ, under the

the two orifices, upon which the said two Pillars stand, and rest. Consider secondly, that the *Potentia* or force of the Pillar  $AP$ , is just equal to the *Pondus* of the Pillar  $ECA$ : Item, that the *Potentia* of the Pillar  $BQ$ , is equal to the *Pondus*  $GDB$ . Thirdly, that the *Potentia* of  $AP$ , is most exactly equal to the *Potentia* of  $BQ$ , and the reason is, because their tops  $A$  and  $B$ , are parts of the same horizontal surface. I say then, if  $AP$  be equal to  $ECA$ , and  $BQ$  equal to  $GDB$ , and  $AP$ , and  $BQ$ , equal among themselves, then must  $ECA$  be equal to  $GDB$ . The same Water then, doth not counterpoise two Bodies of different weight. I grant  $ECA$  to be far heavier, than  $GDB$ , while they are weighed in a pair of scales, but the one is not heavier than the other, as they are weighed in this *balance of nature*.

From what is said, we see first, that in  $V$  Water there is a *Pressure*, and a considerable weight. This is evident from the rising of the Mercury.  $VV$ e see secondly, that Fluids counterpoise one another, only according to *Altitude*. Thirdly, that when a lighter Fluid presseth up a heavier, there is no more prest up of it, than is the just weight of the pressing Fluid, because the Mercury  $EC$ , is just the weight of the  $V$  Water that presseth upon  $XYO$ . That's to say, the part of the surface  $C$ , is no more prest with the Mercury  $EC$ , than the part  $X$ , is prest with the  $V$  Water  $LZX$ . Fourthly, if Mercury were 28 times heavier than  $V$  Water, only three inches would be prest up: if it were but seven times heavier, the altitude would be at  $S$ , 12 inches above  $C$ . Fifthly, it's as easie for a large part of a surface, to sustain a large Pillar, as 'tis for a narrow part, to sustain a narrower Pillar: because  $AP$  sustains  $ECA$ , as easily, as  $BQ$  sustains  $GDB$ .  
Sixthly,

Sixthly, that in Fluids there is a *pondus* and a *potentia*: as is clear from the *potentia* of A P, that sustains the *pondus* of E C A. The VVater likewise that sustains, hath a *potentia*, and the Mercury E C is the *pondus* of it. Seventhly, that there is alwayes equality of weight between the *pondus* and the *potentia*. So is the *potentia* of A P, equal to the *pondus* E C A. Eighthly, that the *pondus* begets the *potentia*. So the weight of the VVater, begets the *potentia* that's in A P. For make this VVater deeper, and you augment the *potentia* of A P. If you subtract from it, the *potentia* of A P grows less by proportion. Or the weight of E C A, may be said to beget the *potentia* of A P. To proceed a little further, let us suppose the Air H E to be removed. In this case, the Mercury rises 29 inches higher than E, or 35 above C; even as high as S. In the narrow Tub it will climb up to K, if you take away the Air I G. This comes to pass, by vertue of the Pressure of the *Atmosphere*, that rests upon L N. From this we gather ninthly, that there is a counterpoise between the Air H E, and the weight of the Air that rests upon L N, and that a slender Pillar of Air, is able to counterpoise a thicker: for H E is far narrower than L N. Tenthly, that the Pressure of the Air, can be communicated thorow divers kinds of Fluids, because the weight that rests upon L N, is sent down thorow the VVater L Z X, and down thorow the stagnant Mercury, and thrusts up the Liquor from A to S, 35 inches. Eleventhly, that a lighter Fluid may be made to press with greater burden, than a Fluid *naturally* heavier, because the weight of the Air upon L N, raises 29 inches of Mercury, but the VVater raises only six. VVe see twelfthly, that Fluids have a sphere of activity, to which they are able to press



press up themselves, or Fluids of different kinds: because first, the stagnant Mercury can raise it self no higher within the Pipe, than it is without. Next, the 84 inches of Water, can raise the Mercury no higher than E. Lastly, the weight of the *Atmosphere*, can raise the Mercury no higher than S, 29 inches above E.

For another trial, take out from among the Water, the two Pipes, and stopping closely the two under orifices, fill them with Mercury to the brim. Then thrust them down as before, and open the said two orifices, while they are below the surface X Y O, and you will find the whole Cylinder fall down from H to E, and there halt: and the whole Cylinder in the narrow Pipe falls down from I to G. Or, if you please, before this be done, stop closely the orifice H, and the orifice I, and you will find the Mercury go no further down than S, by opening the orifice A; and no further down than K, by opening the orifice B. This leads us to a clear discovery of the reason, why the Mercury subsides, and sinks down from the top of the Tub in the *Baroscope*, to the 29th inch, whatever the diameter of the Pipe be. And this lets us see, that the Mercurial Cylinder is suspended by the Air, after the same manner, that the Mercury E C is suspended after: and that there is no more difficulty in the one, than in the other.

## EXPERIMENT XVII.

Figure 23, 24.

**T**HIS Schematism represents a Water 30 fathom deep. Under the first surface A, there are six imaginary, as B C D E F G, every one whereof, is five fathom below  
S
another,

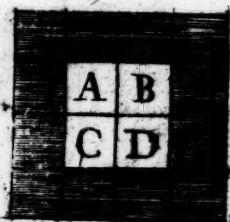


Fig. 18  
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Fig. 19  
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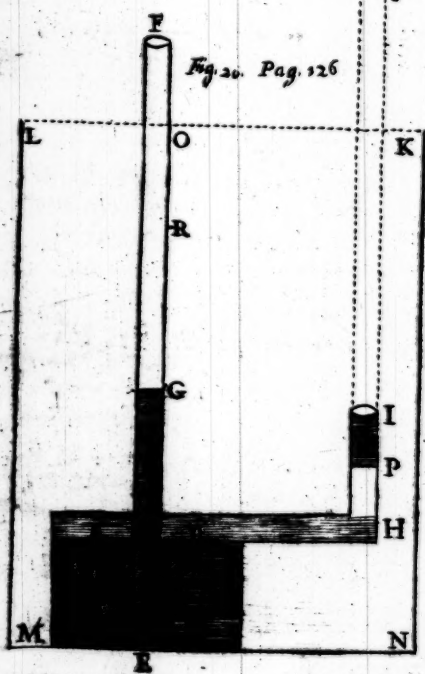
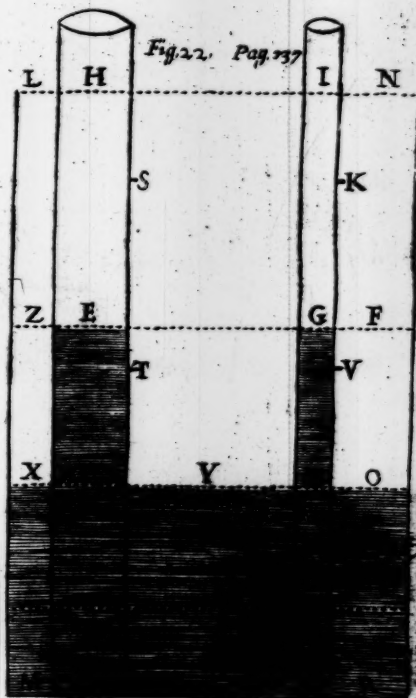
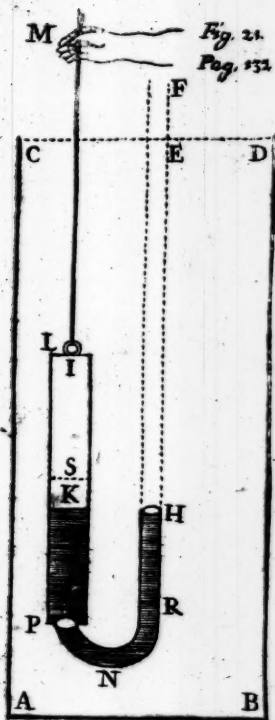


Fig. 20. Pag. 126

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another. There are here likewise two Glasses, each one 12 inches high, and 5 inches broad, like unto these, wherein Wine, Sack, or Brandy is preserved. The Glass G M hath its orifice G upward. The other Glass is completely open below, without a narrow orifice. For making Experiment, take a long chord, as long as the Water is in deepness, and knit the end of it round about the neck of the Glass at G. Take another line of the same length, and fasten it to the bottom of the other Glass at L. Next, for sinking the two Glasses, take two weights of Lead, and fasten the one to the bottom at M, and the other to the open part of the Glass at S, and T. The two weights then, are P and Q, each one of them about 10 or 12 pound weight. These things being done, let first down the Glass G M, till the weight Q sink it five fathom, namely from A to B, and if you pull it up, you will find the bottom covered with Water, from M to I, about four or five inches. Let it down next, from A to C, ten fathom, and you will find more Water in it, even as much as fills it from M to 2, about seven or eight inches. In passing from C D, the Water rises from 2 to 3. If you sink it, from D to E, the Water rises from 3 to 4. The Water rises from 4 to 5, when the glass is come the length of F. And lastly, when the Glass is at G, the lowest fathom, the Water is as high as K. Let down next, the other Glass from A to B, and you will find the Water rise in it from H to 1, four or five inches, as in the other Glass. In going down from B to C, it rises from 1 to 2. From C to D, it rises from 2 to 3. From D to E, it rises from 3 to 4, and so forward, till the Glass come to the lowest fathom, where the Water rises as high as I.

There

There are here several *Phenomena* to be considered. First, that the Water *creeps* in at the orifice G, and fills the under part of the Glass from M to K. Secondly, that *not one particle* of Air comes out, all the time the VVater is in going in. Thirdly, that this Air is comprest from M to K, nine inches. Lastly, that the ingress of the Water, is according to *unequal proportion*: because while the Glass passeth from A to B, more VVater *creeps* in at G, and fills the bottom, then in passing from B to C. And more in going down from B to G, than in going down from C to D, as is clear from the unequal divisions 1, 2, 3, 4, 5, 6. For understanding the reason of the first; remember that in this deep Water, there is a Pressure, and that this Pressure grows, as the VVater grows in deepness. It is then by vertue of this, that the VVater *creeps* in, and fills the bottom of the Vessel: for in effect, every part being under a burden, and being therefore desirous to liberat themselves from it, they take occasion to thrust in themselves, finding, as it were, more ease here, than without, the Air within the Glass, being under less Pressure, than the VVater without. The second *Phenomenon* is caused by the straitness and narrowness of the hole G: for this entry being no wider, than the thickness of a Sack-Needle, the Air cannot go out, while the VVater is coming in; that is, the passage is so strait, that the one cannot go by the other. This leads us to the reason of the third, for if not one *particle* of Air go out, all the while the Glass is in going down, then surely, the VVater filling between M and K, must comprest the Air, and reduce it from twelve inches to three. But the greater difficulty is, why the ingress of the VVater is according to *unequal proportion*. For understanding this, consider, that this

inequality, is not caused by any unequal Pressure that's in the VVater; for if this were true, then there ought to be less Pressure in the surface F, than in the surface E, and less in E, than in D, which is false and absurd. This inequality then, must flow from the nature of the Air it self, that naturally suffers compression after such a manner. 'Tis evident from the compression of Air in *Wind-guns*; for less force is required to compress the first span, than to compress the second: or contrariwise, more strength is required, to compress the third span, than the second; more to compress the fourth, than the third, and so forth. 'Tis evident in all bodies endowed with *Bensil*, as in the *Spring of a Watch*, that requires more strength to bend it, in the end, than in the beginning.

For a second trial, pull up from the bottom of the Water the Glass L I H, and when it comes above, you will find nothing in it. The reason is, because the Vessel being open between T and S, the whole VVater I H, falls down by degrees; but in effect, is really thrust out, by the strong *Bensil* of the compressed Air I L, that now expands it self, when it finds the Glass go up thorow the VVater, whose Pressure is less, and less from the bottom to the top, but the contrary effect follows, when the other Glass is pulled up; namely, the VVater remains within the Glass, and the Air above it, is thrust out by degrees, as the Glass comes nearer to the top. For understanding the reason of this, consider first, that while the orifice G, is level with the lowest surface, where it now is; that's supposed to be 30 fathom deep, there is a real counterpoise between the inclosed Air G K, and the ambient VVater without: for with what force the one strives to be in, with the same force the other endeavours to be out; and because they are in equal



equal terms, therefore the one cannot yeeld to the other. If you please to give the victory to the Water, then let the Glas go further down: but if you desire the Air to overcome, then must the Glas be pulled up. Pull it then up from the place it is in, till it come to F, and you will find a considerable quantity of Air come out at G, and after 2 or 3 minuts of time, emerge and come to the top A, in form of round Bells, or Bubbles. The deepness and grosseness of the Water thorow which the Bubbles come, makes their motion so slow. The reason of this eruption, must be less Pressure of Water in the surface F, than in the lowest G, from whence the Glas came. Suppose then, the lowest to have six degrees of Pressure, F to have five, E to have four, D three, C two, and B to have one: and supposing the inclosed Air KG, to be equal in force to the Pressure of the lowest fathom, it must then have six degrees of *Bensil* in it. Put the case then, that with six degrees of *Bensil*, it come to the surface F, that hath but five, it must surely break forth, and overcome the force and power of that surface: for 'tis impossible that two Fluids can be unequal in force and power, but the strongest must overcome, and the weakest yeeld: therefore, when the orifice comes to F, the Air being stronger than the Water, breaks forth, and as long doth this eruption continue, as inequality of power continues between the one and the other. In pulling up the Glas from F to E, other five fathom, more Air comes out. The reason is the same, namely less Pressure in E than in F: therefore, when the inclosed Air, that hath five degrees of *Bensil*, comes to E, that hath but four, it must overcome, and so long must it be victorious, till by expanding it self, it be reduced to the *Bensil* of four. In pulling up the Glas from E to D, more Air yet breaks out;

out, because a surface of three degrees of Pressure, is not able to resist four degrees of *Bensil*. In passing from D to C, more Air comes yet out for the same reason, till in going up to the top, where there is no Pressure, no more Air breaks out.

'Tis to be observed first, that the motion of the Air up thorow the Water is but slow, the *medium* being thick, and gross. Secondly, that if the Glass be pulled up quickly, from one surface to another, or contrariwise, let down quickly, it presently breaks in pieces. This comes to pass through the strong *Bensil* of the inclosed Air, that must have time to expand it self, otherwise it breaks out at the nearest: for it being of six degrees of *Bensil*, and coming quickly to a surface of five, there happens an unequal Pressure, the sides of the Glass being thrust out, with greater force, than they are thrust in with. But if so be, the Glass move slowly up, the inclosed Air gets time to thrust it self out by degrees, so that whatever surface the Glass comes to, there is little difference between the Pressure of the Water, and the *Bensil* of the Air. The reason why the Glass breaks in pieces, while it goes quickly down, is likewise unequal Pressure upon the sides: for in passing quickly from a surface of five degrees, to a surface of six, the sides are prest in with greater force, than they are prest out with, and the reason is, because through the straitness of the hole G, the Water cannot win in soon enough, to make as much Pressure within, as there is without. 'Tis to be observed thirdly; that if the orifice G be stopped, before that the Glass be sent down, it will not go beyond three or four fathom, when it shall be broken in peices; though the motion were never so slow: and this comes to pass, through the strong Pressure  
of

of the Water. Fourthly, the stronger the Glass be in the sides, it goes the further down without breaking: therefore a round *Glass Bottle*, will sink 20 or 30 fathom, before that it be broken with the Pressure of the Water. If a Vessel of iron were sent down, it ought to go much further. An empty *Cask*, or *Hogshead*, will not sink beyond seven or eight fathom, without breaking, or bursting; yet a Bladder full of wind, knit about the neck with a Pack-Threed, will go down 100 fathom, yea 1000 without bursting.

It may be here inquired, what sort of proportion is kept by the *unequal ingress* of the Water? I answer, it may be known after this manner. Let first down the Glass one fathom, and having pulled it up again, measure the deepness of the Water in the bottom, of it. Next, having poured out that Water, let it down two fathom, and pulling it up, measure the deepness, which you will find more, than afore. Do after this manner, the third time, and the fourth time, till you come to the lowest fathom, and you will find the true proportion.

From what is said we see first, that in Water there is a Pressure, because through the force and power of this Water, the 12 inches of Air that filled the Glass, are reduced to three. Secondly, that this Pressure grows, as the Water grows in deepness: because there is more Pressure in B, than in A, more in C, than in B; and so downward. Thirdly, that when Air is compressed, by some extrinseck weight, the *Bensil* is intended, and grows stronger by *unequal proportion*, as is clear from the unequal divisions, 1, 2, 2, 4, 5, 6. Fourthly, two Fluids cannot cease from motion, so long as the *potentia* of the one, is unequal to the *pondus* of the other: this is evident  
from

from the Water's creeping in at G, all the while the Glass is in going down; and from the Air's coming out, all the while the Glass is in coming up. Fifthly, that no sooner two Fluids come to equality of weight, but as soon the motion ends: because, if the Glass halt at D, E or F, in the going down, upon which follows a counterpoise, then doth the creeping in of the Water cease. Sixthly, there may be as much Pressure in a small quantity of a Fluid, as in the greatest: because there is as much *Bensil* in the small portion of Air, included between K and G, as there is of Pressure, and weight, in this whole Water, that's 30 fathom deep. Seventhly, that the Pressure of a Fluid, is a thing really distinct, from the *natural weight*: this is evident from the Pressure of the inclosed Air GK, that's more and less, as the Pressure of the Water KM, is more and less, but the *natural weight* is still the same, being the same quantity remains. Eighthly, one part of a Fluid, cannot be under Pressure, but the next adjacent, must be under the same degree of Pressure: this is also clear, because what ever degree of *bensil* the included Air KG is under, the Water KM is under the same. Therefore, when the one is under six, as in the lowest fathom, the other is under six likewise. And when the one is under five degrees of Pressure, as in the surface F, the other is under as much. Ninthly, *Bensil* and Pressure are equivalent to *weight*: because the Water KM, is as much burdened with the *Bensil* of that small portion of Air above it, as if it had a Pillar of Water 30 fathom high upon it. Tenthly, that the Pressure of Fluids, is most uniform and equal, and that two Fluids of different kinds, may press as uniformly, as if they were but one: this is evident from the sides of the Glass, that are not broken  
in

in pieces, by the strong *Bensil* of the inclosed Air, and heavy Pressure of the inclosed Water; and this happens because the Pressure without, is as strong as the Pressure within. We see lastly, that *Water does not weigh in Water*, because when a man lets down this Glass by the chord, to the lowest surface, he finds not the weight of the Water *K M*, that's within the Glass, but only the weight of the Lead *Q*. 'Tis certain, he finds not the weight of the Water *I H*; because it rests not upon the Glass within, but is sustained by 'its own surface, the mouth of the Glass being downward, and open. When I say *Water does not weigh in Water*; the meaning is not, that Water wants weight or Pressure in it, but that this weight and Pressure is not found, as the weight and Pressure of other bodies are found, while they are weighed in Water. For example, a piece of Lead or Gold, hung in the Water by a string, the other end being fastened to a Ballance in the Air, *gravitates*, and weighs down the Scale; and the reason is, because Lead and Gold, are naturally and *specifically* heavier than *V Water*; but a piece of Metal of the same *specifick* weight with Water, or *V Water* it self, cannot *gravitate* in *V Water*, or weigh down the Scale of a Ballance; and the reason is, because the surface of Water upon which they rest, bears them up with as great weight and force, as they press down with. If it be said, that the Water *K M*, rests upon the bottom of the Glass within; and therefore, if the man above, find the weight of the Glass, he must find the weight of the Water within it. I answer, the consequence is bad, because the weight of the Water within, is sustained, and counterpoised by the weight of the Water without, whereupon the bottom of the Glass rests. That's to say, as there is a Pillar of Water *K M* within

the Glass, that presseth down the bottom, so there is a Pillar of Water without the Glass, whereupon the bottom of the Glass rests, and which bears up both. But the greater difficulty is this, the further down the Glass goes, it grows the heavier, because of more and more Water, that creeps in at G. Now 'tis certain, the weight Q grows not heavier, therefore it must be the Water within the Glass, that makes the increase of the weight; and therefore Water must still weigh in V Water. If this argument had any strength in it, it would prove the weight of the V Water I H to gravitate and weigh likewise; because the further down this glass goes, it grows the heavier, because of more, and more Water, that creeps up from H to I. Now 'tis certain, the weight of Lead B grows not heavier. Behold, the difficulty is the same in both, and yet it were rashness to affirm the Water I H to be found by a mans hand, when he pulls up the Glass with a string, seeing it is sustained by its own surface, and not by any part of the Glass. Though this might suffice for an answer, yet because the contrary is maintained by some, and that with a new Experiment to prove it, I shall be at some more pains to vindicate the truth of what I have said.

This new Experiment to prove that *Water weighs in Water*, I found in a *Philosophical Transaction*, of August 16. Anno 1669. Numb. 50, the Invention whereof is attributed by the publisher, to that honorable and worthy Person Mr. *Boyl*, whose conclusions and trials, I never much called in question, but finding this opposite, and contrary to what I have demonstrated, I shall crave liberty to say, *amicus Socrates, amicus Plato, sed magis amica veritas*; and shall therefore examine it as briefly as may be. The words of the Publisher are as follows.

The



The Author of this Invention is the Noble Robert Boyle; who was pleased to comply with our desires, of communicating it in English to the curious in England, as by inserting the same in the Latine Translation of his Hydrostatical Paradoxes, he hath gratified the Ingenious abroad. And it will doubtless be the more welcome, for as much as no body, we know of, hath so much as attempted to determine, how much Water may weigh in Water, and possibly, if such a Problem had been proposed, it would have been judged impracticable.

The Method or Expedient, he made use of, to perform it, as near as he could, may easily be learned by the ensuing account of a Trial or two, he made for that purpose, which among his Notes he caused to be registred in the following words.

A Glass-bubble of about the bigness of a Pullers egg, was purposely blown at the flame of a Lamp, with a somewhat long stem turned up at the end, that it might the more conveniently be broken off. This Bubble being well heated to rarify the Air, and thereby drive out a good part of it, was nimbly sealed at the end, and by the help of the Figure of the stem, was by a convenient Weight of Lead depressed under Water, the Lead and Glass being tyed by a string to a Scale of a good Ballance, in whose other there was put so much weight, as sufficed to counterpoise the Bubble, as it hung freely in the midst of the Water. Then with a long Iron Forceps, I carefully broke off the seal'd end of the Bubble under Water, so as no Bubble of Air appear'd to emerge or escape through the Water, but the Liquor by the weight of the Atmosphere, sprang into the un-replenish'd part of the Glass-Bubble, and fill'd the whole cavity about half full, and presently, as I forerold, the Bubble subsided, and made the Scale was fastned to, preponderate so much, that there needed 4 drachms, and 38 grains to reduce the Ballance to an equilibrium. Then taking out the Bubble with the Wa-

ter init, we did, by the help of a flame of a Candle, warily applied, drive out the Water (which otherwise is not easily excluded at a very narrow stem) into a Glass counterpoised before; and we found it, as we expected, to weigh about four drachms and 30 grains; besides some little that remained in the Egg, and some small matter that might have been rarified into vapors, which added to the piece of Glass that was broken off under Water and lost there, might very well amount to 7 or 8 grains. By which it appears not only, that Water hath some weight in Water, but that it weighs very near, or altogether as much in Water, as the self same portion of Liquor would weigh in the Air.

The same day we repeated the Experiment with another sealed Bubble, larger then the former (being as big as a great Hens-egg) and having broken this under Water, it grew heavier by 7. drachms and 34 grains; and having taken out the Bubble, and driven out the Water into a counterpois'd Glass, we found the transvased Liquor to amount to the same weight, abating 6 or 7 grains, which it might well have lost upon such accompts, as have been newly mentioned. Thus he.

#### Figure 24.

**T**He design then of this Experiment is to prove that Water weighs in Water; but, it seems, there is here a very great mistake, which I shall make out after this manner. For which cause, let this Schematism 24 represent the Experiment already described. The Glass-bubble then is E P F R. The stem is H C: the weight that sinks the Glass is B. The surface of Water under which it is drowned, is A D. The Ballance to which the Glass is knit by a string is N O. And lastly E F R is the Water that came in, and filled the half of the Bubble.

Now

Now I say, it is not the weight of the Water E F R, that turnes the Scales above, and makes an alteration in the Ballance, but 'tis only the weight of the Lead B, that does it. For evincing this, consider that all heavy bodies, are either lighter in *specie* than Water, as cork, or of the same *specifick* weight with it, as some Wood is, or lastly heavier in *specie* than Water, as Lead or Gold. Now 'tis certain, that bodies of the first sort cannot weigh in Water, and the reason is, because they being naturally lighter, their whole weight is supported by the Water, and therefore not one part of them, can be born up by a Ballance above. A piece of Cork that weighs 12 ounces in the Air, weighs nothing in Water, because as soon as it toucheth the surface, the whole weight of it is supported, and therefore cannot affect the Ballance above. But bodies of the third sort, as is clear from experience and reason, does really weigh in Water: And the reason is, because they being naturally heavier than water, their whole weight cannot be supported by it, and therefore some part of them must burden the Ballance, to which the body is knit. A piece of Lead, that weighs 12 ounces in the Air, will not lose above 2 ounces, when 'tis weighed in Water, or may be less. But here there is no difficulty. The question then is, in order to bodies of the same *specifick* weight with Water, as some Wood is, or as Water is. I say of such also, that they cannot weigh in Water, and the reason is, because they being 'ust of the same weight, must have their whole weight supported by it; even as one foot of Water, supports the whole weight of the foot above it. It may be evidenced after this manner. Take a piece of Wood, that's lighter in *specie* than Water, and add weight to it by degrees, till it become of the same

same weight with Water. Knit it with a string to a Ballance, and weigh it in Water, and you will find the whole weight supported by the Water. And the reason is, because, being left to it self, it can go no further down, than till the upper part of it, be level with the surface of the Water. Now, the whole weight being thus supported, not one ounce of it can burden the Ballance. In a word, the Ballance can never be burdened, unless the body that's knit to it, have an inclination to go to the ground, when left to it self, which a body of the same weight with Water can never have. I conclude then, if a body of the same weight with Water, cannot *weigh in Water*, neither can *Water weigh in Water*, seeing Water is of the same weight with Water. And Therefore the Water E F R, that's now within the *Bubble*, cannot in anywise burden the Ballance above; but must be supported wholly by the Water I K G H, upon which the bottom of the Glas rests. If it be said, that the Glas it self is supported by the Ballance, because 'tis heavier in *specie* than Water; therefore the VWater within that rests upon the sides of it, must be supported likewise by it. I answer, the whole weight of the Glas is not supported, by the Ballance, but only a part; the VWater I K G H supporting the other part. And this part is just as much as is the weight of VWater, that's expelled by the Glas. Now, if the said VWater support so much of the Glas, because it is the just weight of so much VWater, why should it not also, support the VWater within the Glas? Seeing the VWater within the Glas, is just the weight of as much VWater, as will fill the space E F R.

I come in the next place to shew, that it is the weight  
of

of the Lead B that turns the Scales, when the VVater comes in at C, and fills the half of the sphere. For understanding this, let us suppose first, the weight that's in the Scale O to weigh six ounces. Secondly, that the Glas takes 12 ounces to sink it compleatly under the surface A D. Thirdly, the weight B to be 18 ounces; namely for this cause, first, that 12 of it may sink the Glas; next, that the other six may counterpoise the six in the Scale O. Lastly, that the VVater within the Glas weighs six ounces. I abstract from the weight of the Glas it self, which is not considerable, seing the most part of it, is supported by the VVater, and not by the Ballance. Now, I say, 'tis six ounces of the weight B that makes this alteration, and turns the Scales. For if 12 ounces sink the Glas below the VVater, when 'tis full of Air, and no Water in it, then surely six are sufficient to sink it, when it is half full. And the reason is, because there is a less *Potentia* or force in six inches of Air, by the one half, to counterpoise a weight of 12 ounces, than in 12 inches of Air. Therefore this Air, being reduced from 12 inches to six, it must take only six ounces to sink it. If this be, then the other six ounces that now wants a party to counterpoise them, must burden the Ballance, and be supported by the Scale: and therefore, to make a new *equipondium* again, you must make the weight O 12 ounces, by adding six to it, that it may counterpoise 12 of B, the other six being counterpoised by the Air E P F. Let us suppose next, this Glas to be compleatly full of VVater, and the whole Air expelled. In this case the Scale O, must have 18 ounces in it, for making a new *equipondium*. The reason is, because there being no Air in the Glas to counterpoise any part of B, the whole weight of it must be  
sustained

sustained by the Ballance, and therefore in the Scale O, there must be 18. Now, I enquire, whether these 18 ounces, are the *equipondium* of the VVater within the Glass, or of the weight of *Lead B*? 'Tis impossible it can counterpoise them both, seing the VVater is now 12, and B 18. It must then either be the counterballance of the Water, or the counterballance of the *Lead*. It cannot be the first, because 12 cannot be in *equipondio* with 18, It must then be the second. Or if these 18 ounces in the Scale O, be the counterpoise of the Water within the Glass, I enquire what sustains the weight of the *Lead B*? The weight of it, cannot be sustained by the Water, because 'tis a body naturally heavier than Water, it must therefore be sustained by the Ballance, I conclude then, that *Water cannot weigh in Water*. If it be objected, that this conclusion seems to contradict, and oppose the Pressure of the Water, that's been hitherto confirmed with so many Experiments. I answer, the *Pressure of the Water* is one thing, and *Water to weigh in Water* is another. The first is, when one Pillar of Water counterpoises another, or when a Pillar of Water counterpoises a Pillar of Mercury, or is counterpoised by a Pillar of Air, all which is in order to the *Natural Ballance*, wherein bodies weigh only according to altitude. The second is, when VVater is not counterpoised by VVater, or by Mercury, or by Air, or by any other Fluid; but when 'its weighed by a piece of *Lead* or stone in an *Artificial Ballance*, for knowing how many ounces or pounds it is of, as if a man should endeavour to weigh the Water E F R by help of the Ballance above, which in effect is impossible.



## EXPERIMENT XVIII.

Figure 25.

**M**AKE a *Wooden Ark* after this following manner. The Planks must be of Oak, an inch thick. The height 40 inches. The breadth 36. Clofs on all sides, and above, and open below. And because the form is four-square, there must be four Standarts of Timber, in each corner one, to which the Planks must be nailed. Four likewise upon the top, crossing the other four at right angles, to which the cover must be joyned. The sides must be plained, and the edges both plained and gripped in all the parts, that the joynings may be clofs. Upon the top fasten a strong Iron Ring, as at N, through which must be fastned a Rope, of so many foot or fathom. And because the use of this Engine is for *Diving* under the Water, it must therefore be all covered over with Pitch within and without, especially in the couplings. And because this Instrument cannot sink of its own accord, it must have a great weight of Lead appended to it, for that cause, whereupon the *Divers* feet must stand, while he is in going down. The precise quantity and weight of it cannot be determined; because it depends upon the quantity of the *Ark*, which if large, requires a great weight: if of a lesser size, requires a lesser weight. But whatever the dimensions of the *Ark* may be, the weight of the *Lead-en-foot-stool* can easily be found out by trial. This Invention then, is for *Diving*, a most excellent Art, for lifting up of *Guns*, *Ships*, or any other things, that are drowned below the Water. And it is in imitation of the *Diving bell*, already found out, and made use of with success. It is called a Bell, because of the form, that represents a

Church-bell indeed, being round, wide below, and narrower in the top: only, the matter is of Lead. It seems, it is of this mettall, first, because Lead is weighty, and will therefore easily sink: secondly, because it's easily founded, and will by this means, being of one piece, be free of rifts, and leaks: thirdly, it being of Lead, will be of a considerable strength for resisting the force of the VVater, that ordinarily breaks in pieces Vessels that are weak. I cannot well divine and guess the reason, why first it is round, and next narrower above, than below, unless, because its more easily founded after this way, than after another. This device here described is named a *Diving Ark*; first, because it is of Timber, and next, because it saves a man from being overwhelmed with the Waters. I prescribe it of *Wood*, because of less trouble, and expence in making of it. 'Tis four square, because it contains under this Figure, far more Air, than if it were round; even as much more, as a square Vessel 30 inches wide, contains more than a round Vessel 30 inches wide. Now, the more Air, that's in the Vessel, the easier is the respiration, and the longer time is the man able to abide under the VVater, which two things are of great advantage to this Art. For if by a guess we reckon, how much more Air is in the one, than in the other, we will find in the *Ark*, as before it is described, 30 square foot of Air, but in the *Bell*, though it be 36 inches wide, as well above, as below, yet little more than 23 will be found, which is a considerable difference. But far less must be in it, seeing it's narrower above, than below. Besides this advantage, there are others very useful: for being of Wood, it's more tractable. Next, several Knags of Iron may be fastened conveniently to the sides within, to which a man fastning his hands, may keep his body fixed and sure in going

ing down, and coming up. Moreover, if a man were in hazard to be confounded with fear, or lose the right exercise of his senses, and so be in danger of falling out of the *Ark*; or if his feet should slide off the *foot-stool*, and his hands fail him too, a chord knit to one of those, and fastened about his waist or middle, might bring him up, though he were dead. Then, its far easier to cut out a window or two in the sides of it, not very large, but little, as K and I, whereby, they being covered with Glass, a man may see at a distance, what's upon the right hand, and what's upon the left, and what is before. This device is of excellent use, for through the want of it, the *Diver* sees no more, but what is just below him, which sometimes, when he is near the ground, will not exceed the compass of a large Mill-wheel. But if so be, three holes be cut thorow, one on every hand, and one before, he may see as much bounds, and all things in it, as if he were not inclosed, and invironed with a cover. A little schelf likewise may be fixed upon the one side or the other, for holding a Compass with a Magnetical Needle, for knowing how such and such a thing lies in the ground of the Sea. In one of the corners may hing a little bottle with some excellent spirits, for refreshing the stomach, under VVater. Many moe advantages I might name, this Engine being of Timber, but shall forbear; leaving the collection of them to the ingenious Reader, and proceeds to answer some objections, that may be made against it.

First, if this Engine be made of Wood, it will not sink so easily, as being made of Lead. I answer, this difficulty is soon overcome, namely by making the *Foot-stool* the heavier: therefore how light soever it be, a weight may be found to counterpoise it in the VVater. If it be judged

too light in Timber, it may be lined with Lead, especially without. Secondly, if it be of VVood, there must be couplings and joynings in it, and so rifts and leaks in it, through which the VVater may come. I answer, there is less difficulty here, than in the former, because the joyns may be made so close in all the parts, and may be so covered over with pitch, or with some such like matter, that it may defie either Water to come in, or Air to go out. Thirdly, if it be made of VVood, it will be in hazard of breaking by the force of the VVater: for oft times its found, that the strongest *Hoghead* will burst asunder by the Pressure of it, if they go but down 7 or 8 fathom. I answer, this objection flows from the ignorance of the nature of Fluid bodies. If so be then, that a man knew, that the Pressure of VVater is uniform, most equal, and presseth upon all the parts of a body within it alike, no such scruple would occure. I say then, the *Ark*, though no thicker in the sides, than a thin sawen dale, will go down, in spite of all the Pressure that's in the VVater, not only 10, but 20, or 30 fathom, without all hazard. And the reason is, because what Pressure soever is without, to press in the sides, the same degree of Pressure is within to press them out. By this means, there is not one part of the VVater, how deep soever, to which the *Ark* may come down, but there will be found as much force in the Air within, as will counterballance the whole weight without, as will be infallibly demonstrated afterwards. This answers a fourth objection, namely if holes be cut out in the sides of the *Ark*, in stead of windows, the force of the VVater will break the Glasses in pieces, that covers them. There is here no hazard, though the said windows were 12 inches in Diameter: but its not needful they be so large. Its sufficient,

sufficient, if they be 2 inches wide: for a mans eye near to a hole, 2 inches wide, will see a great way about him. There's a necessity the Glasses be joyned in with cement, that Water may not have access to come in, or Air to go out. In such a case ther's no hazard, that the Pressure of the VWater, will break through the windows, or break the Glasses; because the Pressure of the Air within, being of the same force with the strength of the VWater without, the Glasses are kept intire. It may be enquired, what hazard would follow, upon supposition a small hole were pierced in the head of the Ark above, when it is going down? I answer, ther's not so much hazard, as a man would think; provided the hole be not wide, but narrow. If it be wide, not only the VWater comes in, but the Air goes out, the one thrusting it self by the other. If the hole be no wider, than the point of a bodkin is in thickness, ther's no danger at all; for by reason of the strait passage; the one cannot thrust it self by the other, and therefore neither the VWater can come in, nor the Air go out. And this comes to pass, by reason, that the Air within, is as strong as the Water is without. Now, if they be both of the same strength and force, why ought the Air rather to go out, then the Water to come in; or the Water rather to come in, then the Air to go out? I am confident, though the hole were as wide, as a man might thrust in his little finger, yet no irruption of Water, or eruption of Air would follow. This demonstrats clearly, that though a small rift, or leak should happen in the Ark, yet no hazard or danger would follow thereupon. If it be inquired, whither the greatest hazard is from the ingress of the Water, or from the egress of the Air? I answer; ther's no danger from the coming in of the Water from above, because

cause as it comes in, it falls down, and so mingles with the rest below. But if the Air should go out, the *Ark* fills presently full of Water, and drowns the man that is in it.

The next thing considerable in this *Diving Instrument*, is the foot-stool of Lead C D, that's not only useful for a man to set his feet upon, when he dives; but especially for sinking of the *Ark*. For this being made of Timber; and full of Air, cannot of its own accord go down, unless it be pulled, and forced by some weight. It may either be broad and round, or square: if square, a large foot over from side to side, or 16 inches will determine the breadth. By this means, it will happen to be pretty thick, seeing a great quantity of Lead is required. In each corner, there must be a hole, for four chords, by which it is appended to the mouth of the *Ark*. Between it, and the roof within, must be the height of a man and more. The weight of it, cannot be well determined without trial; seeing it depends upon the dimensions of the *Ark*. First then try, how much weight, will bring the top E F G H level with the surface of the Water. When this is found, add a little more weight till it begin to sink, and this will surely take it to the ground, though it were 40 fathom. 'Tis to be observed, that when the top E F is level with the surface, there is here a just counterpoise, namely between the *Lead foot-stool* on the one part, as a *pondus*, and the *Ark* on the other part, as a *potentia*; for with what force the *Ark* endeavours to pull up the *Lead*; with the same force strives the *Lead* to pull down the *Ark*. Hence it is, that as a small weight will turn a pair of Scales, when they are in *equilibrio*; so a small weight added to the *foot-stool* will sink the *Ark*. Though it may seem difficult to determine the just weight of the foot-stool, without trial



as I said, yet I purpose to essay it. For this cause consider that there is no Vessel of VVood almost, if it be once full of Water, but the orifice of it will ly level with the surface of the VVater, wherein it sweems. This proposition is so evident from experience, that it needs no confirmation. From this I gather, that as much weight of Lead or Stone will bring the top of the Ark EFGH, level with the surface of the VVater, as is the weight of the Water, that fills it. If you suppose then the Ark to be 36 inches broad, and 40 inches high, it must contain 30 cubique foot of Water. Now, supposing each square foot of this Water to weigh 56 pound, 30 foot must weigh 1680 pound. This is gathered from trial and experience, for after exact search, I found a cubique foot of Water, in bulk about 16 pints of our measure, to weigh 56 pound. Take then a piece of Lead of that weight, and you will find it make a just counterpoise with the Ark. If any be desirous to know the quantity of it, I answer, if lead be 13 times naturally heavier then Water, you will find that a piece of Lead about 16 inches every way will do it. If it be objected, that when a mans body is within the Ark, the weight of the foot-stool must be less, even as much less, as is the weight of the man, whom I suppose to weigh 224 pound, or 14 stone. I answer, the whole weight of the man is not to be deduced from the foot-stool, but the one half only, and the reason is, because a mans body being of the same specifick and natural weight with Water, it cannot preponderat or weigh in VVater, because magnitudes only naturally heavier then VVater weigh in VVater, as Lead, or Stone; therefore seing the one half of the man is within the Ark, and the other without among the Water, that part only must.

must weigh, that's invironed with Air. This may seem a plausible answer, and might do much to satisfy these, that are not very inquisitive, yet, being examined, it will be found unsufficient. Therefore, I say, there's not one part of the mans body, that weighs within the Ark, or makes it heavier. Yet, I affirm, that when the mans body is within the Ark, a less weight will sink it, then when his body is out of it, even as much less than before, as is the just weight of the one half of the man. For example, if 1680 pound be the just counterpoise of it without the Man, then after the Man is in it, it will take only 1568 pound to counterballance it, supposing the one half of the man to weigh 112 pound, or seven stone: yet it is not the weight of the man that makes this difference. For understanding what's the cause of this alteration, consider, that when a mans body is within the Ark, there is less Air in it, then while his body is out of it, even as much less in quantity, as the bulk of the parts are, that are within. If this be, then must the Ark become heavier, not because the mans body makes it heavier, but because there is less Air, in the Ark, then before, and therefore, there arises an inequality between the weight of the foot-stool and the weight, or rather lightness of the Ark. For if 1680 pound of Lead, was the just counterballance of it, when it had 30 cubique foot of Air within it, it must exceed, when there is less Air in it. But there occurs, here two difficulties, the first is, what's the reason, why as much weight must be deduced from the foot-stool, as is the the precise weight of the one half of the man? Secondly, how shall we come to the true knowledge of that weight, that is, to know distinctly how many pounds or ounces it is of? For answer, let us suppose, that the one half of the  
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the man, is just as heavy, as so much Water equal in bulk to his own half. This may be granted without scruple, seing a mans body is judged to be of the same specifick, and natural weight with Water : and though there should be some small difference, yet it will not make, or produce any insufficiency in the argument, for these demonstrations, are not Mathematical but Physical. Therefore, as much Water in bulk, as is equal to that part of the man, that is within the Ark, must be as heavy, as the half of the man. Now supposing the half of the man, to weigh 112 pound, and consequently that Water, to weigh as much, I affirm the said Water to contain 3456 cubique inches : but 3456 cubique inches, makes exactly two cubique feet, which I gather thus. Seven pound of Water requires 216 cubique inches, because a Cube of six inches, weighs exactly seven pound, therefore according to the rule of proportion, 112 pound will require 3456 inches, which amounts to two cubique foot. The Ark then by receiving the one half of the mans body, loseth two cubique foot of Air, therefore if 30 foot of Air, require 1680 pound weight of Lead to counterpoise it, 28 foot of Air, must require only 1568 pound : therefore to make a new counterballance, you must deduce 112 pound from the foot-stool. This answers both the difficulties. If it be said, that the foot-stool weighs less in Water than in Air, therefore it must be heavier, then 1680 pound. I answer, 'tis needful to abstract from that difference, till the just calculation be once made, and that being now done, I say, that a Cube of Lead 16 inches weighing 1680 pound, ( If Lead be 13 times heavier than Water, ) will lose about 130 pound. The reason is evident, because a heavy body weighs as much

less in VWater than in Air, as is the weight of the Water it expells. But so it is, that a Cube of Lead of 16 inches expells a Cube of VWater 16 inches: But a Cube of VWater 16 inches weighs 130 pound, which I gather thus. 216 inches, or a Cube of six inches, weighs seven pound, therefore 4032 inches, must weigh 130 pound. For if 216 give 7, 4032 must give 130. But to return. Though there be small difficulty to let it down and to sink it 20 or 30 fathom, yet there is no small difficulty to pull it up again. And the reason is this, because the further down it goes, the Air within, is the more contracted, and thrust up, by the Pressure of the Water, towards the roof. By this means, though near the top of the Water, there was little difference between the weight of the *Lead* and the *Ark*; yet 9 or 10 fathom down, the difference is great, the weight of the one, far exceeding the weight of the other, and therefore there must be greater difficulty to pull it up from 10 fathom, than from 5: and yet more difficulty from 20 than from 10. However, yet 'tis observable that, as the *Ark* in going down, becomes heavier and heavier, so in coming up, it grows lighter and lighter: therefore less strength is required, in pulling it up from the tenth to the fifth fathom, than from the fiftenth, to the tenth: the reason is, because in coming up, the Air within expands it self, and fills more space in the *Ark*, which in effect makes it lighter, and more able to overcome the weight of the *Lead*. To make these things more evident, let us suppose, that when the *Ark* is down 18 or 20 fathom, the Air to be contracted by the force of the Water, from LM to PQ 12 inches. Next, that the weight of the *foot-stool* is 1680 pound. Now, if this weight was the just counterpoise of the *Ark*,

at the top of the Water, then surely it must far exceed it now, when it's 20 fathom down, because the Air that was 30 foot, is now reduced to 21. Count then, and you will find, that if 30 require 1680, 21 will only require 1176: therefore the weight of the *Lead*, will exceed the weight of the *Ark*, at 20 fathom deep, by 504 pound. This will be yet more evident, if we consider, that while the top of the *Ark* EFGH, is level with the surface above, the VVater thrust out of its own place by this bulk, is just the weight of both *Lead* and *Ark*. But when its down 20 fathom, and the Air reduced from LM to PQ, there cannot be so much VVater expelled now as before, seeing the space LMPQ is full of VVater. Now, I say, the *Lead* at 20 fathom, must be exactly so much heavier than the *Ark*, as is the weight of the said VVater LMPQ, which in effect will be 504. pound: for its a square body, 36 inches in thickness and 12 in deepness. The weight of the rope is likewise to be considered, that lets down the *Ark*: for the longer it be, and more of it goes out, it's the heavier, and more troublesome to pull up.

There is no way to cure this difficulty, but by finding out a way, how to keep a just counterpoise between the *Lead* and the *Ark*, all the time it is in going down. If the Air within did not contract it self, no difference would happen: but this is impossible, so long as the Water is under a Pressure. The expedient then must be found out another way, namely by knitting a small rope to the iron ring N, in length with the other, to which at certain distances, relating to the fathoms the *Ark* goes down, must be fastned empty little Vessels of Wood, or bladders, which by their lightness, may compensate the decrement

and decreasing of the Air. First then, let down the *Ark* three fathom, and see how much it is heavier than before; and as you find the difference, so fasten to *R* one Bladder, or two, till the *Ark* be brought near to a counterpoise. Secondly, let it go down other three fathom, and observe that difference also, and accordingly fasten to *T* as many, as will reduce the two to a counterpoise again. Do after this manner, till it sink 15 or 20 fathom. 'Tis to be observed, that the further down the *Ark* goes, the difference is the less: therefore less addition will serve: and the reason is, because there is less Air contracted, in passing between the fifth and the tenth fathom; than in passing from the first to the fifth. The proportion of contraction is represented by the unequal divisions within the mouth of the *Ark*, as 1. 2. 3. 4. In a word, by what proportion the decrement of the Air is, by that same proportion must the addition be, upon the rope *SN*. Suppose then, the Air to be diminished four inches, in going down four fathom, which will be 5184 square inches, or three square foot, then surely as much Air must be added to the rope *SN*, by bladders. In going down as far, let us suppose three inches to be contracted; then less will suffice. Though it cannot be determined without trial, how much Air is contracted in three fathom, and how much in six, and how much in nine; yet this is sure, that the decreasing is according to unequal divisions, that's to say, less in six than in four, less in 8, than in six, and less in 10, than in 8; and so downward: and that this is the rule, namely according to what quantity, the Air within the *Ark* is contracted, according to that same measure, must the addition of Air be to the rope. If it be said, that Bladders full of wind, cannot go down thorow the *V* Water without bursting



ing. I answer, 'tis a mistake, because their sides being pliable, and not stiff like the sides of a Timber Vessel, they yeeld, and therefore cannot burst. It's observable that when a bladder goes far down, the sides becomes flaccid and flagging. In this case, the Air, that before, had the forme of the Bladder, and was somewhat ovall, must now become perfectly globular, and round: for 'tis sure, that the dimensions of it are altered by the Pressure of the VVater, namely from more quantity to less: if this be, then the form must be round, seing the Pressure of the Water is most uniform; even as drops of VVater, or Rain from a house side are round upon this account. This second way, may be thought upon also. Make the *Leaden foot-stool* that sinks the *Ark*, not of one piece, but of many, that so, when the Air within it, begins to be contracted by degrees, in going down, a proportionable weight may be subtracted, for keeping a just counterpoise, all the while of the descent. Or because the greatest trouble is in bringing of it up, let the *Diver*, when once he is at the bottom, subtract so much weight from the foot-stool, as he thinks will go near to make a counterpoise, at that deepness. For example, if the weight of the foot-stool be 40 pound heavier than the *Ark*, then let him subtract 30 or 36, which may ly, and rest upon the ground, till it be drawn up, at a convenient time, by a chord. By his means it will be easie to move the *Ark*, from one place to another. Next, there shall be little or no difficulty to pull it up. Nay, upon supposition, the rope were broken, by which it was let down, yet if the *Diver* please, he may come up without any mans help. And this is most easily done, namely by subtracting as much weight, as will make the *Ark* the stronger party. 'Tis to be observed, that  
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when you are at the bottom, and if you make the *Lead* but one pound lighter than the *Ark*, it will surely come up, and cannot stop by the way. The reason is, because a very small weight will turn the Scales, between two bodies, thus weighing in *VVater*. Next, the further the *Ark* comes up, it becomes the lighter, because the Air within it, expands it self the more. But leaving this, let us come to explicate the reason, why the contraction of the Air is not uniform, but rather difform. For if in going down three fathom, three inches be contracted, there will not be other three contracted in going down the second three, but less: and yet less in going down the third three. Two things then are to be explicated here. First, why there is a contraction. Next, why it is after such a manner. As for the first, the contraction is caused by the Pressure of the Water, which gradually increaseth from the top to the bottom; as is clear from the last Experiment: therefore, there being a greater Pressure in a surface six fathom deep, than in a surface three fathom deep, the Air within the *Ark*, must be more contracted in passing between the third and sixth, than in passing between the first and third. When I say more contracted, the meaning is, that more quantity is contracted to less, whereby the *Bend* of it is more intended; or that the Air is more bended. As for the second, we must remember from the last Experiment, that the cause of this, is not from the *VVater*, as if forsooth the Pressure of it, were according to unequal proportion, but from the Air it self, whose kind and nature it is, to suffer compression after such a way. 'Tis evident in *Wind-guns*, whose second span of Air is compressed with greater difficulty, than the first: and the third with greater difficulty, than the second. 'Tis so with

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all bodies endowed with *Besifil*: for as the longer you bend, you find the greater difficulty. As there is a great disadvantage to the man that *Dives*, from the contraction of the Air, so there is a great advantage to him, from this manner and way of contraction; for if it were uniform, according to the Pressure of the Water, then if three fathom compress three inches, six fathom ought to compress six inches, nine fathom nine inches, and so forward, till by going down, either the whole Air, should be compressed to no inches, or else very little should remain for respiration.

The next thing to be taken notice of, is that all the while, during the down going of the *Ark*, there is still equality of weight, between the *Pondus* of the Water, and the *Potentia* of the Air, for with what degree of weight, the Water presseth up the Air, with the same degree of force and power, doeth the Air press down the Water. If this were not, it would be impossible for a man to go down, because of pain. For when one part of a mans body, is less prest than another, there ariseth a considerable pain, which sometimes is intolerable, as is evident from the application of *Ventofo-glasses*. This equality of weight, is the true reason, why respiration is so easie. Yet 'tis to be observed, that a man cannot breath so easily in the *Ark*, under the Water, as above in the Air; not because there is any inequality, between the weight of the Water, and the force of the Air; but only because the quantity of it is little. For when a man sucks in as much Air, as fills his lungs, the quantity must be diminished: if this be, the Water must ascend by proportion, though insensibly. When a man thrusts out the same Air again, the quantity is increased; if this be, then the Water must subside a little, both which cannot be, with.

without difficulty, seing there is a sort of ebbing and flowing both of the Air and of the Water, in every respiration. But it rather seems ( you say ) that this difficulty flowes from the strong, extraordinary bensil, that the Air is under. I answer, as long as the pressure of a Fluid is uniform, though in a high degree, yet there can be no trouble in respiration; because with what force soever, it is driven in upon the lungs, with the same force it is driven out again: therefore, though the Air we live in, were as much again bended as it is, yet (as is probable) we would find no more difficulty in breathing than now. There is one thing makes breathing easie under the Water, in the Ark, namely this; when a man sucks in the Air to his lungs, his breast and belly goes out, and so fills the space deserted by the Air, that goes in. This makes the ebbing and flowing far less.

From this equality of weight between the pressure of the VWater, and the pressure of the Air, we see good ground to say, that though the Ark, were no thicker in the sides, than a thin sawed dale, yet there would be no hazard of breaking. I am confident, though it were no stronger in the sides, than a wine-glass, that's soon broken; yet it might go down 40 fathom without hazard, or danger of bursting. This affords good ground likewise to make windows in the Ark covered with glass: for if the Pressure be uniform, and equal, its impossible they can be broken. The VWater cannot thrust them inward, because the Pressure of the Air, is as able to thrust them outward.

It's certain, the more Air be in the Ark, the more easie is respiration: therefore its more easie to breath, when the Ark is but down 5 fathom, than when it is down 10 or 15. It's probable a man might live within the Ark, it being 40 inches deep, and 36 inches wide, at the deepness of

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ten fathom, near two houres; whereas if it were round, and narrow above in form of a Bell, he could not continue an hour. It were very easie to try how long other creatures might live in it, for example dogs, and such like, or fowls, as hens, pheasants or doves. They might easily be inclosed from coming out; for though the whole mouth of the Ark were shut up, except as much passage, as would receive a mans fist, yet it will operate, as well that way, as the other. And there, a little doore might be made to open, and shut at pleasure. 'Tis observed, that by long tarrying under the Water in the Bell, the Air becomes gross and misty, which hinders a man from seeing about him. The cause of this, are vapors that come from the stomach, lungs and other parts of the body, especially from the stomach, when the *ventricle* is full of meat. It's not fit then, that a man about to *dive*, should eat too much, or drink too much, especially such liquors as *Sack* or *Brandy*, that beget many fumes and vapors. If a man were necessitated to tarry a pretty while below, fresh Air might be sent down from above, in bottles or bladders, even as much as might fill up the place deserted by the contracted Air. 'Tis observed by some, that have been under the Water, that their eares have been so troubled, that for a long time, they have found difficulty to hear distinctly. The reason of this must be from the great Pressure, the *tympanum* hath suffered from the imprisoned Air of the Bell. The Organ of hearing is soon troubled, especially when a man is near to a great gun, when it's fired. And surely, when a man is but 34 foot down, the Air within the Ark, will be of double Bensil: put the case the man go down 68 foot, or 13 or 14 fathom, the Bensil is tripled: that's to say, if the Air above have five degrees of Pressure in it, the Air of the Bell, at 68 foot deep, will

have 15 degrees of Pressure; therefore the *tympanum* of the ear that's but a small and thin *membran*, must be sore distressed; that is overbended, and prest inward; even as, while a man sets upon a drum head a great weight, v. g. a Bullet of Lead or Iron, of 20 or 30 pound, the skin by this, suffers an extraordinary Pressure, whereby it is in hazard to be rent. 'Tis probable, if a man should go very far down, the *tympanum* might be in hazard of breaking, or being rent in two pieces, there being a greater Pressure upon the one side from the Air without, than upon the other side, from the internal Air within, which is thought to be within the *tympanum*.

There remains another *Phenomenon* to be explicated; and it's this: the further up the *Ark* comes from the ground of the Water, towards the top, the Water within it, subsides and settles down more and more, towards the mouth. The reason of it is, because the further up, the Pressure of the Water is the less; and therefore the contracted Air gets liberty to expand, and dilate it self, and so thrusts down the Water from P Q to L M. In a word, by what proportion the Air is contracted in going down, by that same proportion it dilates, and opens it self in coming up. This lets us see, as there is disadvantage in going down, from the contraction of the Air, so there is advantage in coming up; from the dilatation of it. Some think, that the coldness of the Water is the cause, why the Air is contracted in the *Ark*, such are those, who deny the Pressure of it. But this fancy is easily refuted; because in asserting this, they must maintain, the further down, the cold is the greater. If this be, then far more Air must be contracted, in going down from 10 to 15 fathom, than in passing from 5 to 10; seeing as they say, the further down, the



the cold is the greater, and therefore the contraction of the Air must be the greater; that's to say, there must be more quantity of Air contracted in the one space, than in the other. But so it is, that the further down, the contraction is the less. They judge likewise the coldness of the Water to be the cause, why the sides of empty Vessels are broken in going down. But if this be, then a strong Vessel should go no further down than a weak Vessel; seeing cold can pierce thorow the sides of the one, as well as thorow the sides of the other. And why is it, that a bladder full of wind will go down 40 or 50 fathom without bursting, yea 100, and yet a stone-bottle or glass-bottle, cannot go beyond 20 or 30? If cold have in it, that power to break the sides of a strong bottle, it must be far more able to burst the sides of a thin Bladder. This difference is clearly explicated from the Pressure of the Water; but I defy any man to shew the difference from the coldness of it. 'Tis to be observed, that in all such Experiments of sinking of Vessels, as *Hog-heads*, *Barrels*, and *Bottles*, they must be close on all sides. Therefore, if a man desire to know, how far down a Glass-bottle is able to go without bursting, he must stop the mouth of it exactly, with a piece of wood, and cement.

In setting down the dimensions of the *Ark*, I have restricted them to 40 inches high, and 36 inches wide. But if any man be desirous to enlarge them, or make them less, he may do it. Only 'tis to be observed, that the larger the *Ark* be, the *Foot-stool* that sinks it, must be the heavier. Yet it hath this advantage, that it contains much Air, which is the great perfection of it. One of a lesser size hath this advantage, that it's more tractable, and easier to let down, and to be pull'd up. But these things are

best known from Experience, or if a man please, he may calculate.

As the *Ark* is a most useful device for profit, so 'tis excellent for pleasure, and recreation, if a man were disposed to see the ground and channels of deep VVaters, or were inclined to find out *Hydrostatical* conclusions, a knowledge very profitable, and which few have attained to. Though it seem somewhat difficult to enter the *Ark*, and go down below the Water, yet a little use will expell all fear. Then, a man may go down with less hazard, and fear in the *Ark*, then in the *Bell*, because he may conveniently fasten his hands, to each side of the *Ark*, if need were. He may conveniently sit, as in a Chair, all the time of down going, and up-coming, by fixing a little seat in it: he may have windows to look out at: his body may be so fixed, that there needs be no fear of falling out.

If a man were desirous to make *Hydrostatical* conclusions, by *Diving* under the VVater, the dimensions of the *Ark* might be enlarged, so that it might conveniently cover a mans whole body, by which means, having much Air in it, a *Diver* might continue under Water half a day, if need were. Let us suppose then, the height of it to be 8 foot, and the breadth 3 foot, or more. In such a case, a man might continue under the VVater many hours; and yet not one part of his body wet: for if the *Ark* be 8 foot high, and the man 5 foot in stature, at the deepness of 10 fathom, the Water can scarce rise 3 foot in it. But why may not a man come up every half hour, when he finds difficulty to tarry down in a little *Ark*? I answer, he may; but it's trouble and pains to pull him up, and let him down so frequently. And it may so happen, that through want of Air in a small *Ark*, he be necessitated to come up before

Before he end his work. And leaving the work imperfect, he may find difficulty in the second down going, to find sometimes the place where he was, or the thing he was about to lift, *v. g.* a chest of Gold. If it be said, that a great weight of Stone or Lead is required to sink an Ark 8 foot high, which will amount to 4032 pound weight. I answer, 'tis so indeed: but here is the advantage; when it is once below the Surface, there's little more trouble, then with an Ark of lesser dimensions; because of the *equipondium* that's between it, and the weight, that sinks it.

In such a Vessel many trials might be made. As first, that of the *Torricellian-Experiment*, which is nothing else, but a Glas-Tub so many inches long, with a *Mercurial* Cylinder in it of 29 inches high, that's supposed to be kept up at that height by the Pressure of the Air. If this were taken down about 34 foot, 'tis very probable the Mercury would rise other 29 inches. The reason is, because the Air within the Ark, that presseth upon the Surface of the stagnant Mercury, must be under as much pressure again, as the Air above; but the Air above, is able to support 29; therefore this Air must sustain 58. The reason why the Bensil is exactly doubled is this, 34 foot of Water hath exactly as much Pressure in it, as the whole element of Air; therefore, the Air within the Ark, being 34 foot down, must not only have in it the Pressure of the Air above, but the Pressure of the Water likewise: this necessarily follows, because when two Fluids touch, or are contiguous to other, the one cannot be under five degrees of Pressure, unless the other be under as many. According to this reasoning, if the *Ark* go down 68 foot, the Mercury will rise from 58 to 87. If to 102; it rises

116. This reckoning is founded upon this, namely that Water is 14 times lighter than Mercury; and therefore one inch of Mercury requires 14 of Water to support it in a Tub, and therefore, before Water is able to raise 29 inches of it, the Pipe must be 34 foot deep.

For a second trial, blow a Bladder as full of wind as it can hold, and having knit the neck about with a Pack-thread, place it in the *Ark*, and you will find the sides, that hath been stiffly bended become flaccid and feeble, as if the one half of the Wind had gone out, and this will come to pass, before the *Ark* can go down eight or nine fathom. The strong bensil of the Air within the *Ark* is the cause of this: for as the *Ark* goes down, the Air grows stronger, and so at length becomes of that power and force, that it easily overcomes the force and Bensil of the Air of the Bladder, and reducing it to less room, causes the sides become flapping. In this case, the said Air, that was oval, and had the form of the Bladder, must become round in form of a Globe, because of the uniform Pressure, that it suffers from the Air of the *Ark*. When once the *Ark* is down 14 or 15 fathom, take the same bladder, and blow it stiff with Wind, and knit the neck as afore. And you will find that in the up-coming, the sides of it will burst asunder with a noise. When the Bladder is thus full of Wind, 'tis supposed, that there is a sort of counterpoise between it, and the Air of the *Ark*. But as the *Ark* ascends, the Air of it, becomes weaker and weaker, while in the mean time, the Air of the Bladder suffers no relaxation; therefore, when the *Ark* comes near the surface, there arises a great disproportion between the one Air and the other, as to strength, and therefore the Air of the Bladder being the strongest, rents the sides  
in

in pieces, and comes out with a noise. Or, blow it but half full of wind, and you will find before, the Ark come near to the top, the said Bladder to be bended to the full.

For a third trial, take a Glass, such as they use in *Caves*, for preserving of Brandy, and stopping the mouth closely, take it down with you in the *Ark*; and you will see, the sides of it break in pieces, before you go down four or five fathom. The strong Benfil of the ambient Air, is the cause of this. If you take it down with the orifice open, no hurt shall befall it. Or if you stop the orifice in the up-coming, you will find the same hurt come to it. But here is the difference, in the first bursting, the sides are prest inward, by the ambient Air; in the second, the sides are prest outward, by the Air within the Glass.

For a fourth trial, take a round Glass-bottle, pretty strong in the sides, and when it is down with you in the *Ark* 14 or 15 fathom, stop the mouth of it exactly, and when it comes above, you will find a considerable quantity of Wind come out of it, when the orifice is opened. This evidently demonstrates, that the Air within the *Ark*, 12, 13, or 14 fathom down, is under a far stronger Benfil then the Air above.

For a fifth trial, let a man apply to his skin a cold *Cupping-Glass*, when he enters the *Ark*; and he will find such a swelling arise within it, as when it is applied hot by a Chyrurgion. This tumor begins to rise, as soon as the *Ark* begins to go down. The reason is evident from unequal Pressure, the parts within the Glass being less prest, than the parts without.

For a sixth trial, take a common *Weather-Glass*, and place

Place it in the *Ark*, and in the going down, you will see the liquor creep up in it, by degrees, as the *Ark* goes down, as if some extraordinary cold, were the cause of it. And as the *Ark* comes up by degrees, the said liquor creeps down by degrees. The cause of this *Phenomenon* is not cold, as some might judge, but the strong Benfil of the Air within the *Ark*, that so presseth upon the surface of the stagnant Water, that it drives it up. If you take with you, a *Weather-Glass*, hermetically sealed, no such thing will follow; because the outward Pressure is kept off. 'Tis not then cold, that's the cause, but weight. By the way take notice, that all common *Weather-Glasses* are fallacious and deceitful; because the motion of the Water in them, is not only caused by heat, but by the weight of the Air, which sometimes is more, and sometimes less, as frequently I have observed, and as hath been observed by others. This difference is found, by the alteration of the altitude of the Mercurial cylinder, in the *Baroscope*, which is more and less, as the Pressure of the Air changeth. In fair weather, and before it comes, the Mercury creeps up. In foul and rainy weather, and a pretty while, before it fall out, it creeps down. Because in fair weather, the weight of the Air is more, than in rainy and dirty weather. *December, 13. 1669.* I found the altitude 29 inches, and nine ten parts of an inch: at this time the heavens were covered with dry and thick clouds, and no rain followed. *March 26. 1670.* I found the altitude no more, than 27 inches, and nine ten parts, at which time, there was a strong Wind with rain. Between these two termes of altitude, I have found the Mercury move near a twelve moneth. 'Tis a most sure prognosticator, for if after rain,



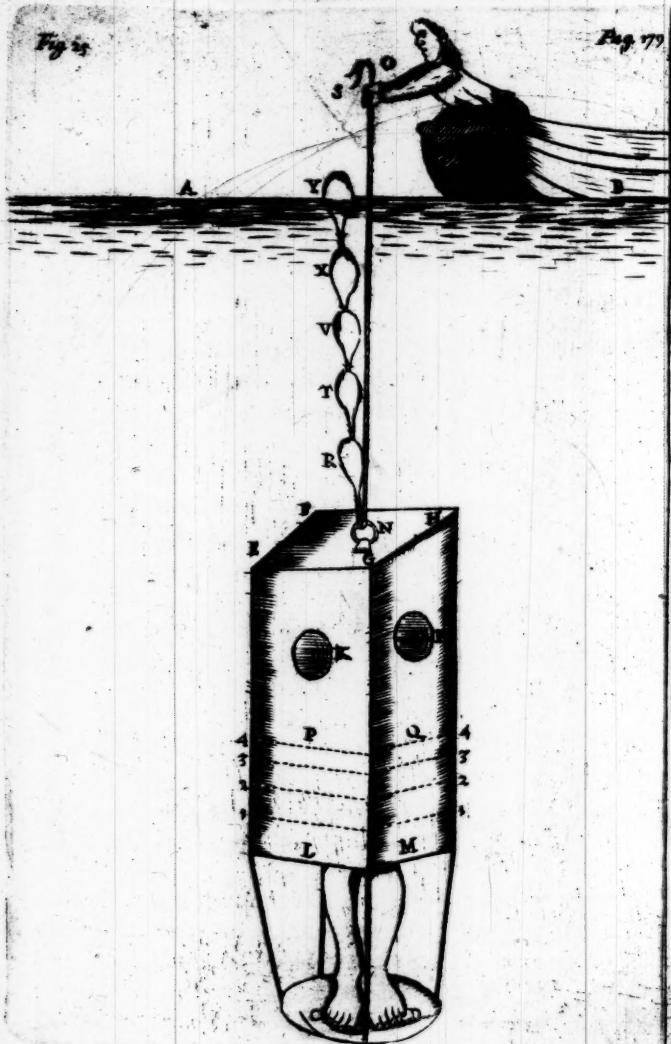
rain, you find the Mercury creep up in the morning, you may be sure, all the day following will be fair, notwithstanding that the heavens threateneth otherways. If after fair weather, the Mercury subside, and fall down a little, you may be sure of rain within a short time, though no appearance be, in the present. It falls down likewise, when winds do blow. What the true cause is, why there is such an alteration in the Pressure of the Air, before foul weather, and fair, and in the time of it, it is not easie to determine.

But we proceed. Trial likewise might be made, by firing a great piece of Ordnance above, whether the report would be heard below the Water or not? This would determine the question, whether Water be a fit *medium* for conveying sound as Air is. Item, whether or not, the Sea water be fresher at the bottom, than near the top, which is affirmed by some. Item, whether sounds be as distinct in such a small portion of Air, as they are above. This might be tried with a Bell of a Watch. If need were, a little chamber Bell might be hung within the *Ark*, and a small chord might pass up from it, through the cover, whereby the persons above, might by so many tingles, speak such and such words to the *Diver*. I have demonstrated before, that though there were a little narrow hole made in the cover above, yet neither Air would go out, nor Water come in. If a man were curious, he might have a window not only in the sides, but in the roof above, covered with a piece of pure thin Glasse, thorow which he might look up, after he is down two or three fathom, and see whether there appeared any alteration in the dimensions of the body of Sun or not, or seemed nearer.

We now come to infer some *Hydrostatical* conclusions, as from former Experiments. We see then first, that in Water there is a pressure; namely from the strong *Bensil* of the Air within the *Ark*, that groweth stronger, and stronger, as the Water groweth deeper, and deeper. We see next, that the pressure of the Water hath an increment: because the further down the *Ark* goeth, the Air is the more bended. Thirdly, two Fluids cannot be contiguous one to another, unless both of them be under the same degree of pressure: because the Air of the *Ark*, and the Water that creepeth up within the mouth of it, are perpetually under the same degree of power, and force, whatever the deepness be. Fourthly, that in Fluids the pressure is uniform; because the Air of the *Ark*, and the Water without, press most equally, one against the other. Fifthly, the more that the Air is bended, it is the more difficult to bend it; and consequently, that the diminution of the quantity, is according to *unequal proportion*. Sixthly, that when the *Ark* is down 34 foot, the *Bensil* of the Air is doubled: and tripled, when its down 68 foot: because the pressure of 34 foot of Water, is as much as the whole pressure, that's from the *Atmosphere*. If it be enquired, how much weight rests upon the palm of a mans hand, when the *Ark* is down about 68 foot? I answer, the pressure of the Water upon a mans hand, at that deepness with the pressure of the Air above, will be equivalent to the weight of a pillar of Mercury 87 inches high; and three inches thick, which will exceed in real weight 200 pound. If so much rest upon the palm, how much must rest upon the rest of the parts of the body? Let us suppose then, the quantity of the palm, to be found in a mans skin, 200 times, then must he suffer as much

Pressure,

pressure, and actually support as much burden, as will amount to 40000 pound weight. Seventhly, our bodies may be under a huge pressure, and yet that burden not perceptible; as is evident from the *Diver*, who findeth little or no weight, while he is under the Water. Or if there be any Pressure found, it's not comparable to that, which really is. Eighthly, when a man is 14 or 15 fathom down, at every inspiration and expiration, his breast and belly must lift up the weight of 1800 pound: because, if the whole burden be 40000, the weight that rests upon the breast, and belly, will be about 1800. Ninthly, that between every inspiration, and expiration, there happens a perfect counterpoise, namely by the Air, that goeth into the lungs, and the outward Air of the *Ark*: for if the Pressure of the one, were more, than the Pressure of the other, there could be no motion of the lungs. Tenthly, when a man draweth his breath, the Air cometh not in by *suction*, but by *pulsion*. For this cause, though the VVind-pipe were stopped, yet a man might live by having a hole in his side, going into the lungs. Lastly, that there is no such thing as *suction* properly; and therefore the motion of all Fluid bodies, is caused by Pressure and weight. The motion of the blood then thorow the heart, is *driven*, and not *sucted*. Infants properly do not suck, but have the milk squeezed into their mouth. 'Tis evident from the sucking-glass that some women use for milking their own breasts: for by help of this, the Air that guardeth the head of the Pap is removed, and so the Air, that presseth the parts about, and without, squeezes out the milk.



## EXPERIMENT XIX.

Figure 26.

THIS Figure represents a deep Water, whose first and visible surface, is F G. The imaginary surface, is E L C, 34 foot below it. A D B is a *Siphon*, working below this V Water with Mercury. A E L is a Vessel with stagnant Mercury, among which the orifice A is drowned, the other orifice B existing among the Water; D M is the height of the *Siphon* above the line of level, which I suppose is 58 inches. For making it work, stop the two orifices closely, and pour in as much Mercury at a hole made at D, as will fill both the legs. Then stopping the said hole, open the two orifices A and B, and you will find the liquor run as long out at B, as there is any almost in the vessel A E L. For evincing this, which is the only difficulty, consider, that if this *Siphon*, were filled with Water, and made to work only with Air, (as is clear from daily experience) the liquor would run out constantly at B. Because there is here an unequal Pressure; the surface of Air N B, being more burdened, than the surface E L C, but where unequal Pressure is in Fluids (according to the 12th Theorem) motion must follow, I prove the surface N B to be more burdened, than the surface E L C, because the Water B D, is heavier than the Water L D, as is evident to the eye. The Air B therefore, sustaining far more weight, than the Air E L, must cede and yeeld. Next, there is here a *pondus* and a *potentia*, the *pondus* is the V Water L D; the *potentia* by which it is counterpoised, is the Water B D; but these are unequal, B D being heavier,

heavier, than  $L D$ ; therefore according to the 33 Theorem, these two Fluids cannot cease from motion. If it be said, that the surface  $N B$  is stronger, than the surface  $E L C$ , seing it is lower. I answer, the difference is so unsensible, that they may be judged but one. Now, I say, if this *Siphon* work in Air, with Water, it must likewise, work in Water with Mercury. Therefore, this *Siphon* being 34 foot below the first surface  $F G$ , the liquor must run out constantly at  $B$ . Because, there is here, an unequal Pressure, the surface of  $V V$ ater  $N B$ , being more burdened, than the surface  $E L C$ . Though there be more weight in  $N B$ , than in  $E L C$ , because it is lower, yet because the difference is not so much, as is between the weight of  $B D$ , and the weight of  $L D$ , it proves nothing. Note here, that so long as  $D$ , is within 58 inches of  $E L C$ , this *Siphon* will work. The reason is, because the Pressure of 34 foot of  $V V$ ater, with the Pressure of the Air, upon  $F G$ , are able to raise Mercury exactly 58 inches. But if  $D$  exceed that height, no Art will make the liquor run out at  $B$ . Note secondly, that this *Siphon* will operate with Air and  $V V$ ater, though the top  $D$  were 34 foot above  $M$ ; and the reason is, because the Pressure of the Air, is able to raise a pillar of Water to that height. Note thirdly, that if there were an orifice opened at  $C$ , upon the level line  $E L C$ , the two Waters would become of the same weight, the one not being able to move the other. If you bore a hole at  $R$ , the liquor ascends from  $R$  to  $D$ , and goeth down from  $D$  to  $A$ , and so the motion ends. But, if the leg  $A D$  were six times wider, than  $B D$ , the liquor would not run out at  $B$ . I shall answer this in the close.

From this Experiment we see first, that the motion of Fluid



Fluid Bodies up thorow *Pumps*, and *Siphons* is not for shunning *vacuity*, but because they are prest up violently. We see next, that when the Pressure is uniform, there is no motion in Fluids; but assoon, as one part is more prest, than another, motion begins: because, this *Siphon* will not operate, if the orifice be made in C; but if so be, it be in D, then the motion begins; because there is here an unequal Pressure, which was not in the other. We see thirdly, that Fluids have a determinate *Sphere of activity*, to which they are able to press, and no further: because this Water, is not able to press Mercury higher than 58 inches. So the Air cannot raise Water higher than 34 foot. If this Water were 68 foot deep, the *Sphere* of it's *activity* would be 116 inches. We see fourthly, that in Fluids there is a *Pondus* and a *Potentia*; and that the inequality of weight between the two, is the only cause of motion. We see fifthly, that as long as this inequality of weight continues, as long continues the motion, because, as long as B D. is heavier than L D, the motion perseveres. We see sixthly, the possibility of a *perpetual motion* in Fluids; because the liquor runs perpetually out at B. If it be said, the motion ends, when the stagnant Mercury A E L faileth. I answer, this stop is only accidental, and not essentially from the nature of Fluids. If it be enquired, whether or not, would the Mercury run out at B, upon supposition, the shank L D were twice as wide, as the shank B D? I answer it would. If it be said that the one is far heavier than the other, namely L D than D B. I answer, weight in Fluids is not counted according to thickness, but according to altitude.

EXPE-

## EXPERIMENT XX.

Figure 27.

**T**His last is for demonstrating the precise and just weight of any Pillar of Air, Water, Mercury, or of any other Fluid body, if some of their dimensions, be but once known. AB then is a square Pipe 12 foot high, and six inches in wideness, full of Water, resting upon the surface of Air AC. And EG is a square Pipe 12 foot high, and 12 inches wide, full of VWater, resting upon the surface of Air EF. None needs to doubt, but the two Waters, will be suspended after this manner, even though the orifices A and E were downward, especially if they be guarded with Water, but the demonstrations, will be the more evident, that wee suppose the two Pillars of Water to be suspended as they are. From this Experiment I say first, that the Pillar of Air CD is 168 pound weight, at least; which I prove thus. The VWater AB is 168 pound: therefore the Air CD, must be as much. I prove the *Antecedent*, because it's a Pillar of VWater 12 foot high, and six inches thick: but every half cubical foot of VWater, that contains 216 inches, weighs seven pound: therefore seing the Pillar is 12 foot, it must contain 24 half feet; but 24 times 7 is 168. The only difficulty is to prove the *Connexion*, which I do thus, from the seventh Theor. *all the parts of a Fluid in the same Horizontal line, are equally prest*, but so it is, that the part A, and the part C, are in the same horizontal surface; therefore the part A, and the part C, are equally prest. But if the part A, and the part C, be equally prest, the Pillar of Air CD, must be as heavy, as the Pillar

Pillar of VVater A B. I say secondly, that the Pillar of Air F H, weighs 672 pound, I prove it thus. The Water E G weighs 672 pound; therefore the Air F H, weighs as much. The *Antecedent* is clear, because E G, is a square Pillar of VVater 12 foot high, and 12 inches thick; but every cubical foot of VVater weighs 56 pound: but 12 times 56, is 672. I prove the *connexion*, as before. All the parts of an horizontal surface, are equally prest; therefore the part F, must sustain as much burden, as the part E.

To proceed a little further, let us suppose the Pipe A B to be 34 foot high, and the Pipe E G to be as much. I assert then thirdly, the Pillar of Air C D to weigh 476 pound, which I prove as before. All the parts of the same surface, are burdened with the like weight, but the part A sustains 476 pound, therefore the part C must support as much. The *Connexion* is evident, and the *Antecedent* is so too, because the VVater A B being 34 foot high, and six inches thick, must weigh 476 pound: for, if 216 inches, weigh seven pound, 14688 inches, must weigh 476 pound. I assert fourthly, the Pillar of Air F H to weigh 1904 pound, which I demonstrat by the former *Medium*. All the parts of a Fluid that ly in the same horizontal surface, are equally prest; but so it is, that E and F, do so ly; therefore F must be as much burdened as E, the Water therefore E G, weighing 1904 pound, the Air F H, must weigh as much. For if 216 inches of Water weigh seven pound, 58752 inches (for so many are in the Water E G) must weigh 1904 pound.

Let us suppose secondly, the Tub A B to be only 29 inches high, and the Tub E G, of the same hight, and that

that six inches wide, and this 12 inches wide. I affirm then fifthly, the Air C D to weigh yet 476 pound, and the Air F H, to weigh 1904 pound. Because the Pillar of Mercury A B, weighs 476 pound, and the Pillar of Mercury E G, weighs 1904 pound: therefore, if A B be 476, C D must be as much. And if E G be 1904, F H, must be of the same weight. I prove the Mercury A B to weigh about 476 pound, though it be but 29 inches high; because it is 14 times heavier then Water. For the same cause, doth the Mercury E G weigh about 1904 pound. I say *about*, because 34 foot, contains 29 inches, more than 14 times.

Let it be supposed thirdly, the Pipe E G, (being 34 foot high,) to have the one half of it I G, full of Air, and the other half E K full of VWater, I affirm then sixthly, the part E, and the part F, to be yet equally burdened. That's to say, the VWater E K, that's now but 17 foot, makes as great a Pressure upon E, as when it was 34 foot. The reason of this, is surely the Pressure of the Air I G, that bears down the Water K E, with the weight of 952 pound, the half of 1904 pound. If it be said according to the Theorem 21, that there is as much Pressure and weight in the least part of a Fluid, as in the whole; therefore the Air I G, must be as heavy as E H. I answer I G, is not so heavy as F H, because the Water E K impending in the lower part of the Tub, hath occasioned the Air I G, to expand it self so many inches, by which means, it loseth so many degrees of it's *Bensil*. If you remove the Water E K, then will the Air I G, be as heavy, as F H; because E K being Air, it reduceth I G to that same degree of *Bensil* with it self; but when the Air E is burdened with the Water E K, it can-

not make the Air I G, of that same weight with it self.

Let us suppose fourthly, that only eight foot and an half of Water, are in the Tub, namely between E and N. I say then seventhly, that the part E, is as much burdened with it, as when the Pipe was full, because the 25 foot, and an half of Air N G, is exactly as heavy, as the 25 foot and an half of the Water that's gone. I prove it thus. The Air E hath the weight of 1904 pound in it self, being the weight of the surface, is alwayes equal to the weight of the Pillar, but being burdened with the VWater E N, that weighs 476 pound, it cannot press up with more weight then with 1428 pound: and therefore the top of the Water N, must press upon the under part of the Air, that's contiguous with it, with 1428. If this be, the Air N G, must press down with as much, being according to the 20 Theorem, it is impossible, that one part of a Fluid, can be under Pressure, unless the next adjacent part, be under the same degree of Pressure. Therefore I conclude, that the 25 foot and an half of Air N G, is as heavy, as the 25 foot and an half of the Water that's gone. This makes it evident also, that when the Pipe is half full of VWater, as E K, the Air I G, hath the weight of 952 pound. Because E being in it self 1904, but being burdened with E K 952, it cannot make the top of the Water K, press upon I with more weight than 952; and therefore (by the 20 Theorem,) the Air G I, must weigh 952 likewise.

I affirm eighthly, that, when the Pipe is full of Water, from E to G, if a man poise it in his hand, he doth not find the weight of the Water E G. And the reason is, because it's sustained by the part of the surface E. But if the Air E sustain it, my hand cannot sustain it. I find then

then only the weight of the Tub, but not the weight of the VVater within it. I say ninthly, that when I poise the said Tub, I find the whole weight of the Pillar of Air L M, which is exactly 1904 pound. I prove it thus. The *pondus* of a Fluid is then only found, when there is not a *potentia* to counterpoise it, or at least, when the *potentia* is inferior to the *pondus*: but there is here no *potentia*, counterpoising the *pondus* of the Air L M. Therefore, I must find the weight of it, when I lift up the Tub. The *major proposition* is clear from the tenth Theorem. It's evident also, from common experience; for while a balance is hanging upon a nail, with six pound in the one scale, and nothing in the other, you will find the whole burden, if you press up that one scale with the palm of your hand. But if so be, there were six pound in the opposite scale, you will not find the first six; and the reason is, because it is in *equilibrio* with other six. 'Tis just so here, I must find the weight of the Air L M, while I poise the Tub, because it wants a weight to counterbalance it. I prove the *minor proposition* thus. If any thing counterbalance the Air L M, it must either be the Air below, namely the part E; or the Water E G; but neither of the twain can do it. Not the Air E, because it hath as great a burden upon it, as it is able to support, namely the Water E G, that weighs 1904 pound. And for this cause, not the VVater it self, seing all the force it can have to counterbalance L M, is from the surface of Air E; but this is in *equilibrio* with it already. I said that the Air L M, was exactly 1904 pound weight. This also is evident, because it is just of these same dimensions, with the Air F H. If it be said, the Air L M must be thicker; seing it's equal to the Tub without; but the Air



FH, is only equal to the Tub within. I answer, it is so indeed; but here is a solution to the difficulty. I do not find the whole weight of the Air LM, but only as much of it, as is equal to FH. Suppose the Tub to be 12 inches within, from side to side, and 16 without, from side to side. I say then, I find only the burden of so much Air, as answers to the cavity of the Tub, because the rest of these inches, are counterpoised, by as much below, namely by the Air, that environs the orifice B: for it's supposed, that if the Tub be two inches thick above, it must be as thick in the lips. So that the whole Tub, is not unequally prest, but only so much of it within upon the top, as answers to the cavity. Tenthly, that when the Pipe is but half full of VVater, namely from E to K, I find only 952 pound of the Air LM, though before I found 1904. The reason is, because the one half of it is now counterpoised by the Air IG, and therefore the weight of it becomes insensible. 'Tis clear from the sixth assertion, that the Air IG, presseth down with 952; therefore it must press up with as much, seing according to the sixth Theorem, the Pressure of a Fluid is on every side. Eleventhly, that when there is only eight foot of VVater and a half in the Tub, namely between E and N, I find only 476 pound of the Air LM. Because in this case, the Air NG counterpoiseth 1428 pound of it. For if the said Air, burden the Water NE, with 1428 pound, as is clear from the seventh assertion, it must likewise press up the Tub with as much, and so counterpoise as much of the Air LM. Twelfthly, that when there is nothing within the Pipe but Air, the whole weight of the Air LM becomes insensible to me. The reason is evident, because it is wholly counterpoised by the Air within the Pipe. I affirm thirteenthly, that the

the Water E G, is in *equilibrio* with the Water A B: that's to say 1904 pound, is in *equilibrio* with 476 pound. I prove it evidently, by the first *medium*; all the parts of an Horizontal surface, are equally press'd; therefore the part A, sustains no more burden, then the part E, therefore A B, is as heavy as E G, and consequently, the Air C D, must be as heavy, as the Air F H. Lest this proposition may seem to contradict what is already said, I must distinguish a twofold Balance, according to the third Theorem, one *Natural*, another *Artificial*. In the *Artificial Balance*, where magnitudes do weigh according to all their dimensions, *viz. Longitude, Latitude, and Profundity*, the Water A B, and the Water E G, are not in *equilibrio* together, seing the one is 1428 pound heavier than the other. But in the *Balance of Nature*, such as these Pipes are, all the four makes an *equipondium* together; because they do not weigh here, according to their *thickness*, but only according to their *altitude*. Therefore seing A B is as high as E G, and seing C D is as high as F H, they must all be of the same weight.

From the first assertion I infer, that one and the same Fluid, even in the *Balance of Nature*, may sometimes be in *equilibrio* with a lesser weight, and sometimes with a greater, because the Air C D, that weighs really 476 pound, is in *equilibrio* with the Water A B, that weighs but 168. This is, when A B is supposed to be only 12 foot high. It's likewise in *equilibrio* with it, when its 34 foot high. But how can A B, that's 12 foot high, press A, with as much weight, as when its 34 foot high? I answer by a similitude; when a Cylinder of Wood 12 foot high stands upon a Table, it may burden it as much, as if it were a Cylinder 34 foot high. For, supposing it to be thrust

thrust in, between it, and v. g. the ceiling of the room above, it must press down with more weight, then it it were not thrust in. So, this Cylinder of Water A B, that's but 12 foot high, being prest between the surface A, and the top of the Tub within, must burden A, as much, as if it were 34 foot high; for being of this height, it only stands upon the surface, without pressing up the top of the Tub.

I infer from the second assertion, that each Pillar in a Fluid hath a determinate weight. This is evident from the determinate weight of A B, that weighs first 168 pound, being 12 foot high, and 467 pound, being 34 foot high, and so of the rest. I infer secondly, that the thicker, and grosser a Pillar of a Fluid be, it is the heavier, (even in the *Artificial Ballance*) and contrariwise, the more slender and thinner it be, it is the lighter. This is evident from the Water A B, six inches thick, that weighs 476 pound, and from the Water E G, 12 inches thick, that weighs 1904 pound. So doth the Pillar of Air C D, weigh less, then the Pillar F H. Here is ground for knowing the certain and determinate weight of a Pillar, in any sort of a Fluid whatsoever. As to Air, its clear and evident, that a four-square Pillar thereof, 12 inches every way, weighs 1904. That's to say, if it were possible, to take the Pillar of Air F H, in its whole length, from the surface of the earth, to the top of the Atmosphere, and pour it into the Scale of a Ballance; it would be exactly the weight of 1904 pound. Here is a secret: though that same Pillar of Air, were no longer, than 6 or 10 foot, yet the Pressure of it, upon the body it rests upon, is equivalent to 1904 pound. If this be, (you say) what is the weight of Air, that rests upon this Table, that's 36 inches square?

square. I answer, it must be as heavy, as a Pillar of Water 34 foot high, and 36 inches thick, which will, by just reckoning, amount to 17136 pound, or to 1071 stone weight. It may be inquired next, what's the weight of the Air, that burdens the pavement of this parlour, that's 16 foot square? I answer 487424 pound. Because it is exactly the weight of a bulk of Water 34 foot high, and 16 foot thick. 'Tis to be remembered, that though the Pressure of it, be so much, yet being poured into the scale of a Ballance, it will not weigh so much: for not only as much as fills the room must be taken, but as much as passeth from the pavement to the top of the *Atmosphere*. According to this method 'tis easie to determine the weight of any Pillar of Air whatsoever, provided a man but once know the thickness of it, both the wayes, e.g. there's a *planum* 12 inches long, and six inches broad, upon which rests a Pillar of Air. The weight of it then is, just the burden of a magnitude of Water 34 foot in height, 12 inches in length, and six inches in breadth.

Though the weight of any Pillar of Air may be known, by knowing only the dimensions of it, in breadth and length; yet the weight of a Pillar of Water cannot be known, unless all the three common dimensions of it, be first known. The reason is this, the Pillars of Air, are all of the same height, but the Pillars of Water in the Ocean, are of different heights: therefore, not only must they be known, *secundum longitudinem, & latitudinem*, in length and breadth, but *secundum profunditatem*, that is, according to deepness. 'Tis easie to know then, what each particular Pillar weighs. First then, try how much weight is in a cubical foot of Water, and having found this to be v.g. 56 pound, you may determine, that a Pillar

Pillar of Water 34 foot high, and 12 inches thick, weighs 1904 pound. A Pillar 34 foot high, and six inches thick weighs 476 pound. Note, that in a Cube of Water six inches thick, there are 216 inches, which weighs seven pound. In a Pillar 12 inches thick, and 20 fathom, or 100 foot high, you will find 5600 pound weight. In one, of the same thickness, but 200 fathom high, there are 56000, fifty six thousand pound weight. In a Pillar three foot square, and 20 fathom deep, there are 50400, fifty thousand, and four hundred pound weight. Make it 200 fathom high with that thickness, and it will weigh 504000, five hundred and four thousand pound. But, if according to the Theorem 25, you consider the weight of the Air above, it will weigh 521136, five hundred, twenty and one thousand, one hundred thirty and six pound. A Pillar 12 foot square, and 300 fathom deep, weighs 12096000, twelve million, ninety and six thousand pound. Lastly suppose there were a bulk of Water 500 fathom deep, and 500 fathom thick, such a magnitude would weigh 8750000000, eight thousand seven hundred, and fifty million of pounds. But if the Pressure of the Air, that rests upon a surface of Water 500 fathom in breadth and length, be taken in, that weighs 119000000, a hundred and nineteen million of pounds, the total, that the bottom of the sea sustains, must be 8940000000, eight thousand, nine hundred and fourty million of pounds, or 558750000 five hundred fifty and eight million, seven hundred, and fifty thousand stone weight.

Infer from the fifth assertion, that the lightest of Fluids may be brought to an *equilibrium* with the heaviest. For though Mercury be 14000 times heavier than Air,

yet

yet the part of the surface A, is no more prest with the Mercury A B, then the part C is prest with the Air C D. Secondly, that 29 inches of Mercury, are of the same weight with 34 foot of Water. Thirdly, the heavier a Fluid be naturally, it hath the less altitude in the *Natural Ballance*; and contrariwise, the lighter it be, it hath the more altitude. This is clear from the Mercury, that's 29 inches, the Water that's 34 foot, and the Air, that's counted 6867 fathom.

I infer from the sixth assertion, that two Fluids of different *gravities*, may make an *equilibrium* with a third of the same kind. Because the 27 foot of Air I G, and the 17 foot of Water E K, are in *equilibrio* with the Air F H. I infer secondly, that 17 foot of Air, may be as heavy as 17 foot of Water, because the Air I G, is exactly as heavy, as the Water E K. I infer thirdly, that the *Bensil* of a Fluid, is a thing really distinct, from the *Natural weight* of it: because the Pressure of the Air I G, is 952 pound; but the natural weight of it will not exceed, if it were weighed in a Ballance, two or three ounces. I infer fourthly, that Air cannot suffer dilatation, but it must lose of it's Pressure. Because the Air I G, that ought to weigh 1904 pound, weighs only 952. For understanding this, you must know, that when a Pipe is about half full of Air, and half full of Water, and inverted, so much of the Water falls out, and consequently so many inches doth the Air above it, expand it self. So to make this Pipe that's 34 foot high, half full of Air and half full of Water, you must pour in about 19 foot of Water, and the 15 foot of Air that's in it besides, will, when the Pipe is inverted, go up and expand it self to 17 foot, two foot of Water falling out.

B b

I in.



I infer from the seventh assertion, that when there are two Fluids of different gravities, and weights counterpoising a third, by what proportion the one grows lighter, by that same proportion the other becomes heavier. For, when the V Water E K, that weighs 952 pound, becomes B N, that weighs 476, the Air above it, that weighed 952, becomes now 1428 pound.

I infer from the eighth, that the *pondus* of a Fluid, cannot be counterpoised, by two distinct *powers*. Because the 34 foot of Water E G, cannot be both sustained, by the part of the surface of Air E, and my hand. I infer from the ninth, that the Pressure and weight of a Fluid, may be found, even in its own Element, by *sense*. Because in poising of the Tub, I find the weight of the Air L M. I infer secondly, that the *weight* of a Fluid is only found in its own Element, when there is not a *potentia* to counterpoise the *pondus* of it, because I find only the weight of the Air L M, because it wants a *potentia* to counterpoise it. I infer thirdly, that it is very possible even in the *Artificial Balance*, to weigh a Fluid in its own Element, and to know the precise weight of it, to a grain. For this cause, take a small chord, and fasten therewith the top of the Pipe G, to the Scale of a Ballance, and the Lead or Stone that makes the counterpoise in the opposite Scale, is the just weight of the Air L M.

I infer from the tenth, that by how much the nearer, the *potentia* of a Fluid, comes to the *pondus*, by so much the less, is the *pondus* found, or is sensible. This is clear, because I find less of the weight of the Air L M, it being counterpoised with the Air I G, than before. This follows likewise from the eleventh assertion. I infer from the twelfth, that when the *pondus* of a Fluid, is counterpoised,  
by

by an equal *potentia*, it becomes altogether insensible, and I infer from the last, that two Fluids differing in weight, according to the *Libra* or *Artificial Balance*, may agree in weight, according to the *Natural Balance*. I infer secondly, that Fluids in the *Balance of Nature*, do not counterpoise one another according to their *thickness*, but only according to their *altitude*.

To put a close to this Experiment, let us suppose the Pipe E G to be 68 foot high, and void of Air. If then the orifice E be drowned among stagnant Water, the Liquor of its own accord (as it were) will rise from E to K 34 foot, the other half I G remaining empty. This evidently shews, that the Pressure of the Air, hath a *Sphere of Activity*, beyond which it is not able to raise or press up a pillar of Water. 'Tis folly then to think that Water may be conveyed over high places by the help of a *Siphon*, v. g. from the one side of a Hill over the top, to the other side. For, if that hight exceed perpendicularly 34 foot, no Art will do it. Yet contrariwise, it is possible to transport Water, by Pipes and Siphons, not only 34 foot below the source, but 3400. Nay, if there were a *Siphon* passing from the surface of the Earth to the Center, and thence rising to the surface again, it would convey Water from the one place to the other. For 'tis a certain and infallible rule in the *Hydrostaticks*, that Water will rise as high in this place, as the hight of the place is, from whence it comes, even though the windings and turnings of the *Lead-Conduits* underground were as a *Labyrinth*, and though this place, were not only 1000, but 5000 pace distant from the other. 'Tis to be observed, that if the mouth of the *Conduit*

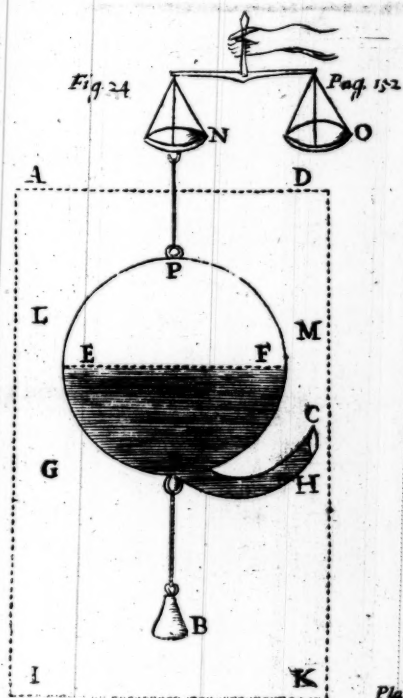
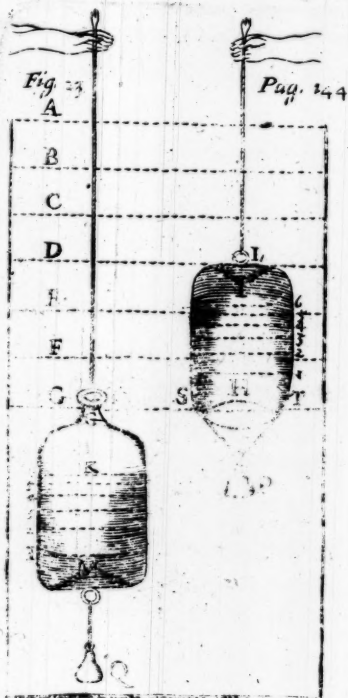


Fig. 26.

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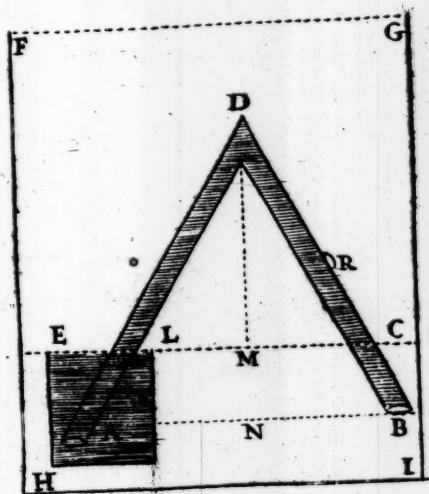


Fig. 27

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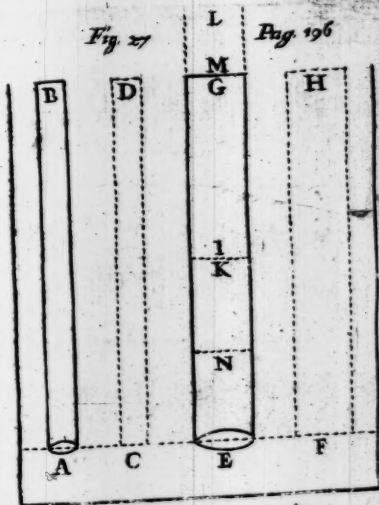
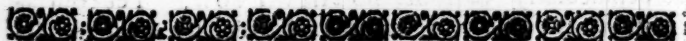


Fig. 28

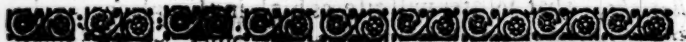
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here, be exactly as high as the other end at the Fountain, the Water stands still. And the greater the difference be, the Water flows out with the greater force. By the help of such *Conduits*, 'tis easie to convey Water to a City many miles. Such Pipes are ordinarily made of Lead. But for saving expence, they may be made of Timber, or Clay well burnt in an Oven.



AND





AN ACCOMPT' OF  
**Miscellany**  
**OBSERVATIONS,**  
 Lately made, by the Author of the  
 foregoing EXPERIMENTS.

OBSERVATION I.

**I**N *May 1669*, there was need of a new Sink, on the east side of *Tranent*, for winning of *Coals*. But while the *Coal-hewers* were in digging down, and had come the deepness of 13 or 14 fathom; they were stopped from working by *Damps*, or ill Air, that flowed out plentifully from the sides of the sink, wherein there were a great number of *Cutters*, or rifts, out of which that ill Air came. To try the nature and power of *Damps*, I took a dog, and fastned him in a *bucket*, with a small roap, that he might not leap over, and when he had gone down 7 or 8 fathom, he presently begins to howl, and cry pitifully, as if he had been beaten.



beaten sore with a rod, and a little after, he begins to stagger, and his feet failing him, he falls down, as one overtaken with the Epilepsy, and in going down to the bottom, his eyes turning in his head, they appeared very shining and clear like two large bright Diamonds. Fearing, that the *Damp* should have killed him out of hand, he was instantly pulled up from the bottom, where he had not tarried 15 seconds of time. And when the bucket had come to the mouth of the *sink*, he was pulled out, and laid upon the ground, to get fresh Air. When he had lien a while as dead, he begins at last to gape, and gasp, and make some respirations, as if he had been rather expiring, than recovering. Next, he began to stir and move his feet, and after, to raise himself upon his knees, his head staggering and wavering from side to side. After a *minut* or two, he was able to stand upon his feet, but so weakly, that he was not in capacity to walk or run. Yet at last, being much refreshed, he escaped from us, and ran home, but slowly. In the afternoon, the same Experiment was repeated, with another dog, whose case was the same in all things. But after he was perfectly recovered, for a further trial, we let him down the second time, and suffered him to tarry in the bottom of the *sink*, about the space of three minuts: but when he was pulled up, and taken out, we found no symptomes of life in him; and so after half an hour and more, his body began to swell, which ordinarily befalls such, who are killed after this manner. After this, we sent down in the Bucket, a little Chicken, which, when it came near the *Damp*, presently flapped with the wings, and falling down, turned over and over for a pretty while, as if it had been taken with a *vertigo*, or giddiness. But by drawing up the Bucket in haste, and bringing the Bird to the fresh Air, it recovered. In the evening.

evening, we let down a *lighted Candle*, but it was soon extinguished, when it came near mid-sink; for here, rather than in the bottom, was the strongest *Damp*. Lastly, we let down by a chord, a *Brand-iron*, with burning Coals, whose flame was soon put out, and after a little while, we perceived the red Coals to be extinguished by degrees; yet not totally, because, as the Coal-hewers observed, the power of the *Damp* was not so strong, as before. These *Damps* then have their ebblings and flowings, which seem to depend upon the weather, or rather upon the situation of the winds, and their force. For 'tis observed, that a high South-west wind causeth ill Air in this place; and that, by reason of much wast ground, that lies upon the South, and South-west hand of this *Sink*, whence are conveyed under ground by secret passages, which are nothing else but so many rifts and openings, commonly called by the Coal-hewers, *Cutters*, corrupted and rotten Air, full of sulphurious stems. The reason why these passages are open, and replenished with nothing, but corrupted Air, is this, the Water, that's ordinarily called the Blood of the Coal, being withdrawn with subterraneous Gutters (commonly called *Levels*) that are digged, and wrought under ground, sometimes a very long way, for drying of the *Mines*, and the veins of the earth being now empty, there succeeds Air; which Air, by process of time, and long standing, rots, and contracts a sulphurious quality, which causeth sudden death. Now, when the wind is high, and strong from the South or South-west, that sulphurious Air is driven through the ground, and coming to *Sinks* and *Mines*, where men are working, presently infects the place, and hinders the work. 'Tis often observed, that the wind and Air under ground, keep a correspondence in their motion,

on, with the wind above ground : and therefore, when the wind is in such a point above, 'tis found, that the motion of the Air below runs such a way, and the contrary way, when the wind above ground, is in the opposite point. When there is a free passage between the bottom of the two Sinks, you may observe the wind come down through the one, and running alongst under the ground, rise up thorow the other, even as Water runs thorow a *Siphon*. For this cause, when the *Coal-hewers* have done with such a *Sink*, they do not use to stop it, or close it up, but leaves it standing open, that the Air under ground may be kept under a perpetual motion and stirring, which to them is a great advantage. 'Tis very strange to see sometimes, how much Air, and how fresh it will be, even at a very great distance, namely four or five hundred pace, from the mouth of the *Sink*. This could never be, unless there were a considerable Pressure and weight in it, whereby it is driven forward, thorow so many *Labyrinths*. And even in the utmost room, where the *Coal-hewers* are working, the Pressure is as great, as it is above ground, which is found by the *Torricellian Experiment*. In such a case, the Air cannot press down thorow the Earth and Metalls, therefore the Mercury must be suspended, not by a Pillar from the *Atmosphere*, but by the *Bensil* of it. Nay, put the case, that the whole Element of Air were destroyed, and this remaining, yet would it be able to support 29 inches. To shut up this discourse, it is observed by the *Coal-hewers*, that when there is ill Air in a *Sink*, a man may perceive distinctly, what is lying in the bottom, so clear and transparent is the Air of it: but when the *Damp* is gone, the *Medium* is not so clear. In temperat and cold weather, the *Damps* are not so frequent. From this *Sink*, in soft winds, or in Northerly winds, or when it blows from East or North-east, the *Damps* are driven away. O B-

## OBSERVATION II.

**J**upiter upon Wednesday night, at eleven a clock, being 24 of November, 1669, had the following position with the stars of *Gemini*. He was so near to the Star C, that to appearance, the points of his rayes did touch it. This Star by looking upon the material Glob, is fixed in the very *Zodiask*, and in the 13 degree of *Cancer*, and is the very navel of the following *Twine*. The Star A is *Castor*. The Star B is *Pollux*. The star D, is fixed in the forefoot of the following *Twine*. From this place he moved, with a retrograde motion, till he came to the 5 of *Cancer*, about the 20 of February, 1670, and from that time became *Direct* in his motion, and so upon the 27 of March, 1670 at 9 a clock, he was in a right line with *Canis minor*, and the brightest Star in *Auriga*, and was in a right line with the eastmost shoulder of *Orion*, and *Castor* in *Gemini*, or with that Star, when South-west, that's highest, and West-most.

## OBSERVATION III.

**I**T is written in the History of the *Royal Society*, that such a member of it, whose name I have forgotten, hath found out, among many other curious inventions, this, namely a way for knowing the motion of the Sun in seconds of time: but is not pleased to reveal the manner how. Because such a *device* may be usefull in Astronomy, and likewise for adjusting the *Pendulum Clock*, I shall therefore briefly shew, the manner and way how such a thing may be done, as I have tried it my self. I took an Optick Tub, about 12 foot long, only with two Convex  
C c glasses

glasses in it, and did so place it in a dark room, by putting the one end, in which was the *object-glass*, without the window, and keeping the other within, that I caused the beams of the Sun shine thorow it, which were received upon a white wall four or five foot from the Tub. This image, which was perfectly round, and splendid; did move alongst the wall very quickly, so that in a minut of time, it did advance seven inches and a half, which will be the eight part of an inch in a *second*, a motion very sensible. Now, this beam that came thorow the Tub, and lighted upon the wall, would not have moved one inch in a minut, if it had wanted the two Glasses, for as they magnify, and seem to bring nearer the *object*, so they quicken the motion of it. In a word, by what proportion the *object* is made more, by that same proportion is the motion quickned. 'Tis to be observed, that the longer the Tub be, the motion is the swifter: for as the longest Tub doth ordinarily most magnify the object; so doth it most quicken the motion. Next, the farther distant the white wall is from the end of the Tub, the larger is the image; and contrariwise, the nearer it be, it is the less. Thirdly, the farther the wall be from the end of the Tub, the circumference of the image is the more confused; and the nearer it be, it is the more distinct. Fourthly, the darker the room be, it is so much the better. Lastly, this trial may be made with ordinary *Prospects*, of a foot, two foot, or three foot long, which will really do the thing, but not so sensibly, unless the glasses be very good.

As to the use of this device in Astronomy, I shall not say much. But shall only mention what it may serve for in order to the Pendulum Clock. For this cause, let a  
man

man choise a convenient room, with a window to the South, wherein this Tub may be so fixed, that it may ly just, or very near to the true *meridian*, and may move *vertically* upon an axil-tree, because of the Suns declination every day. Then at a certain distance from the end of it, fix and settle a large board of timber, smooth, and well plained, and well whired, for receiving the image. In the middle of this board, draw a circle with Charcoal, equal in diameter to the circle of the image. Now, this being done, you will find that as soon as the west side of the Sun, begins to come near to the *Meridian*, the image begins to appear upon the board, like the segment of a circle, and grows larger, and larger, till it become perfectly round. Now in the very instant of time, wherein the image, and the circle are united, set the wheels of your Clock a going, from the *hour*, *minut*, and *second* of XII. To morrow, or 3 or 4 dayes after, when you desire to make an examination, wait on about 12 a clock, when the Sun is coming to the *Meridian*, and you will find what the difference is. If the *Clock* go slow, observe, as soon as the image is united with the circle (which you will perceive in a *second* of time) the variation, that's to say, how many *seconds* intervene between that *second*, wherein the union fell, and that *second*, that closes XII hours in the *Clock*. If it go fast, observe how many *seconds* pass from that *second*, that ends XII hours, and that wherein the image of the Sun is united with the circle, which if you do, you will know exactly, what the difference is, even to a *second*. But without this, you will find great difficulty to know the variation in 15 or 20 *seconds*, especially in a common *Dial*. But here, you will see distinctly the image of the Sun move every *second*



of time, the eighth part, or the sixth part, or the fourth part of an inch, according to the length of your Tub, and goodness of your glasses. 'Tis to be observed, that in adjusting the *Pendulum Clock*, respect must be had to the table of *Equation of dayes*, commonly known in Astronomy. For if this be not, it is impossible to make it go right, and that because all the natural dayes of the year, are not equal among themselves: that's to say, the time that's spent by the Sun's motion from the *Meridian* this day, to the same *Meridian*, the next day, is not equal, but is more or less, than the time spent betwixt *Meridian* and *Meridian*, a third or fourth day after. For instance, the Sun this day being 11 of *July*, comes sooner to the *Meridian* by three *seconds* of time, than he came yesterday. Within 9 or 10 dayes, (suppose the 22 of *July*) he will be longer in coming to the *Meridian* by 4 *seconds*, than upon the 21. This difference I grant, in short time is not sensible, yet once in the year, it will amount to more than half an hour. This inequality of dayes arises from two causes. First, from the Sun's *eccentricity*, whereby he moves slower in one part of the *Zodiack*, than in another: for in Summer when he is furthest from the Earth, he goes slower back in the *Ecliptick*, than in Winter, when he is nearer to it. The second cause, which is truly the far greater, is this, because in the diurnal motion of the Sun, equal parts of the *Equator*, does not answer to equal parts of the *Zodiack*. Hence it followes, that if the natural dayes be not equal among themselves, the hours must be unequal also: but this is not considerable.

By help of such a Tub placed in a dark room, it is easie, when the Sun is under Eclipse, to enumerat distinctly

ly the digits eclipsed. Likewise, if you take out the object Glass; and cover a hole in the window board with it, you shall see distinctly upon a white wall, the *species* and true representations of all objects without. And by comparing the quantity of the object without, with the quantity of it within, you may know the distance of it from the window, though it were many miles. For as the one quantity, is to the other, so is the distance between the Glass and the object on the wall, to the distance between the Glass and the object without.

It may be inquired whether or not, the *retrograde*, as well as the *diurnal motion* of any of the Planets, may be discerned, in *minuts* or *seconds*, by the help of a long Telescope? In answer to this, we must suppose the Planets only to have a *retrograde* motion, and consequently to move slowly from West to East, *Saturn* once in 29 years, or 30, to run about the *Zodiack*; *Jupiter* in 12, *Mars* in 2 years; the Sun in one year, *Venus* and *Mercury* in less time, and lastly the *Moon* in a moneth. Now I say, it is impossible by the longest Tub, that the greatest Artist can make, to discern the motion of the inferior Planets, far less the motion of the superior, either in *Minuts* or in *Seconds*, and that by reason of the great tardity, and slowness of the motion. Notwithstanding of this, I am induced to think, that the retrograde motion of the *Moon* might be discerned, at least in *Minuts*. For evincing of this, let us suppose which is true, that the *Sun* runs from East to West half a degree in two *Minuts* of time, seing in an hour he runs 15 degrees. Next, that the *Moon* goes about the *Zodiack* in 27 dayes and 7 hours, namely from that same point, to that point again, and consequently runs back every day 13 degrees and about

10 Minuts. By this account, she must *retrograde* half a degree, and about 2 minuts of a degree every hour. The *Sun* then runs half a degree in two *Minuts*, and the *Moon* half a degree in 60 *Minuts*; therefore the *Moon* must be 30 times slower in her *retrograde* motion, than the *Sun* is in his diurnal motion. Let us suppose next, as I observed with a Tub 12 foot long, that the image of the *Sun* runs the eighth part of an inch every *second*, and consequently, seven inches and an half, in a *Minut*: then must the image of the *Moon* with that same *Telescope*, run the thirtieth part of seven inches and a half in a *Minut*, seing she runs 30 times slower; therefore in every *Minut* of time she must advance the fourth part of an inch, which will be very sensible. Though we grant, that the *Moon* hath no *retrograde* motion properly, yet by comparing the diurnal Motion of the *Moon*, that's slower, to the diurnal motion of the *Sun*, that's swifter, we shall really find the thing it self. Therefore in the time of a *Solar Eclipse*, this *retrograde* motion is conspicuous, which by an ordinary *Telescope* may be discerned in *Minuts*. As soon then as the East side of the *Moon*, begins to enter upon the West side of the *Sun* (the greater the *Eclipse* be, it is the better) observe, and you will find the one image, which will be black, cover the other by degrees, that's splendid, and run in every minut of time, the fourth part of an inch of the *Sun's* diameter, provided alwayes, that the *Sun* run the eighth part of an inch in a *second*.

## OBSERVATION IV:

UPON Tuesday the 19. of July 1670, the following Experiment was made. In the middle Marches between Scotland and England, there is a long tract of Hills, that run from *Flowdon*, many miles South and South-west, amongst the which, the Mountain *Cheviot* is famous beyond, and conspicuous above all the rest for altitude, from whose top a man may discern with one turning of his eye, the whole Sea-coast from *New-castle* to *Berwick*, much of *Northumberland*, and very many Leagues into the great *German Ocean*: the whole *Mers* and *Teviotdale*, from the foot of *Tweed*, to very near the head of it: *Lauderdale*, and *Lammer-moor*, and *Pentland-hills* above *Edinburgh*. The North side of this Mountain is pretty steep, yet easie to climb, either with men or horse. The top is spacious, large and broad, and all covered with a *Flow-moss*, which runs very many miles South. When a man rides over it, it rises and falls. 'Tis easie to thrust a Lance over the head in it. The sides of this Hill abounds with excellent Wellsprings, which are the original of several Torrents, amongst the which *Colledge-Water* is famous, upon which, not a mile from the foot of this Mountain is *White-hall*. The adjacent Hills are for the most part green, and excellent for the pasturage of Cattel. Not many years ago, the whole Valleys near the foot of *Cheviot*, were Forrests abounding with *Wild-Deer*.

Upon the highest part of this Mountain was erected the *Torricellian Experiment* for weighing of the Air, where we found the altitude of the *Mercurial Cylinder* 27 inches and an half. The Air was dry and clear, and no wind. In our Valley-Countreys, near to the Sea-Coast, in such Weather,

Weather, we find the altitude 29 inches and an half. When this difference was found, care was taken to seal up closely with *Bees-wax*, mixed with *Turpentine*, the orifice of the Vessel, that contained the stagnant Mercury, and thorow which the end of the Pipe went down. This being done with as great exactness as could be, it was carried to the foot of the Mountain in a Frame of Wood, made on purpose, and there opening the mouth of the Vessel, we found the Mercury to rise an inch and a quarter higher than it was. The reason of this strange *Phenomenon* must be this, namely a greater Pressure of the Air at the foot of the Hill, than upon the top: even as there is a greater Pressure of Water in a surface 40 fathom deep, than in a surface 20 fathom deep. 'Tis not to be doubted, but if the root of the Mountain had been as low as the Sea Coast, or as the surface of *Tweed* at *Kelso*, the *Mercurial Cylinder* would have been higher. This way of observing, seems to be better than the common: for while the *Baroscope* is carried up and down the Hill, without stopping the orifice of the Vessel, that contains the stagnant Mercury, the *Cylinder* makes such reciprocations, by the agitation of a mans body, that sometimes abundance of Air is seen to ascend up thorow the Pipe, which in effect makes the *Cylinder* shorter than it ought to be. But if so be, the end of the Pipe be immersed among *Quick-silver*, contained in a Glass with a narrow orifice, so that it may be stopped completely, you will find no reciprocations at all. And to make all things the more sure, the Glass may be filled up either with *Mercury*, or with Water above the *Mercury*; by which means the *Cylinder* in the down-coming, or in the up-going shall remain immoveable. Besides the stopping of the orifice of the said Glass, you may have a wider Vessel,

fel, that may receive the same Glass into it, and it being full of Water, may so cover the sealed orifice, that there shall be no hazard of any Air coming in. Or this Experiment may be first tried at the root of the Hill, and having stopped compleatly the mouth of the Vessel, the whole Engine may be carried up to the top, where you will find the *Mercury* subside and fall down so much; namely after the said orifice is opened: for as the stopping of the orifice at the root of the Hill, is the cause, why that same degree of Pressure remains in the stagnant Liquor; so the opening of it upon the top of the Hill, is the cause why it becomes less.

This Experiment lets us see, that the Pressure of the Air seems to be as the Pressure of the Water, namely the further down the greater; and the further up the less: and therefore, as by coming up to the top of the Water, there is no more Pressure, so by coming up to the top of the Air, there is no more weight in it; which in effect says, that the Air hath a determinat height, as the Water hath. From this Experiment we cannot learn the determinat height of the Air, because the definit height of the Mountain is not known. I know there are some, who think that the Air is indefinitely extended, as if forsooth, the Firmament of fixed Stars were the limits of it, but I suppose it is hard to make it out.

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OBSERVATION V.

**J**une 5. 1670. I observed the *Sun* within 3 *minuts* of setting, to have a perfect *oval figure*, the two ends lying level with the Horizon. His colour was not red as ordinarily, but bright and clear, as if he had been in the

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Meridian:



*Meridian*: neither was the Sky red, but clear also. And by the help of the *Pendulum Clock*, I have observed his body to be longer in setting than it ought, by eight *minuts*, and sometimes by *ten*, and his Diameter longer in going out of sight than it ought, by two, and sometimes by three *minuts*. The reason of these *Phenomena*, must be the *Refraction* unquestionably.

## OBSERVATION VI.

**U**Pon *Saturday* evening the 30 of *July* 1670, and the night following, till about two a Clock in the *Sabbath* morning, there fell out a considerable rain, with great thunder, and many lightnings. About *Sun-set*, the convocation of black clouds appeared first towards the *Horizon* in the South-west, with several lightnings; and the wind blowing from that point, carried the clouds and rain over *Mid* and *East-Lothian*, towards the *Firth* and *Seacast*. About 9 a clock, the whole Heavens almost were covered with dark clouds, yet the rain was not very great, neither were the *thunder claps* frequent, but every *fifth* or *sixth second* of time, a large and great lightning brake out. But before the *thunder crack* was heard, which happened every fourth or fifth *minut*, the lightning was so terrible for greatness, and brightness, that it might have bred astonishment. And because the night was very dark, and the lightning very splendid, a man might have perceived houses and corn-fields at a great distance. And if any had resolved to catch it, in the breaking out, it did so dazle the eyes, that for half a *minut*, he was not able to see any thing about him.

Sometimes the lightning that went before the thunder,  
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brake forth from the clouds, like a long spout of fire, or rather like a long flame raised high, with a Smiths Bel-lows, but did not continue long in sight. Such an one above the Firth was seen to spout downward upon the Sea. Sometimes there appeared from the one end of the cloud to the other, an *hiatus*, or wide opening, all full of fire, in form of a long furrow, or branch of a River, not straight, but crooked. I suppose the breadth of it, in it self, would have been twenty pace and more, and the length of it five or six hundred pace: the duration of it, would have been about a second of time. Sometimes a man might have perceived the nether side of the cloud, before the crack came, all speckled with streams of fire, here and there, like the side of an Hill, where Moor-burn is, which brake forth into a lightning. But there was one, after which followed a terrible thunder crack, which far exceeded all the rest, for quantity and splendor. It brake out from the cloud, being shot from North to South, in form of fire from a great *Cannon*, but in so great quantity, as if a Gun ten foot wide, with 500 pound weight of Powder in it, had been fired. And surely the lightning behoved to be far greater in it self, seeing it appeared so great, at so great a distance. It did not evanish in an instant, like the fire of a Gun, but continued about a second and an half, by reason (it seems) that it could not break out all at once. This did so dazle the sight, that for half a minut almost, nothing was seen, but like a white mist flying before the eyes. The whole Countrey about was seen distinctly.

All these great lightnings were seen a considerable time, before the crack was heard. Sometimes 30 *seconds* numbered by the *Pendulum Clock* interveened, namely when the thunder was at a distance, about 7 or 8 miles. Some-

times 15 or 16 only interveened. But when the thunder was just above our head, no more passed, than 7 or 8, which seems to demonstrat, that these thick black clouds, out of which the thunder breaks, are not a *Scottish* mile from the earth, when they are directly above us.

'Tis observable, that in all lightnings, and thunderings, there is no smoke to be seen, which seems to evince, that the matter whereof they are generated, must be most pure, and subtil. Who knows, but this Countrey, that abounds with *Coal*, may occasion more thunder and lightnings, than other places, namely by sending up sulphurous exhalations to the middle region of the Air, wherewith the *Coal-mines* abound.

#### OBSERVATION VII.

**T**His is a method for finding out the true South and North Points, which are in effect very difficult to know. Take therefore four pieces of Timber, each one of them five foot long, and about six inches thick, square-wise. Sharpen their ends, and fix them so in the ground, that they may stand Perpendicular, and as near to South and North, by a *Magnetick Needle*, as may be. The place would be free of Trees, or of any such impediment, that it may have a free prospect of the Heavens. As for their distance one from another, let the two North-most, and the South-most be two foot asunder: let the two East-most, and two West-most, be but one foot, making as they stand, an *oblong quadrangle*. For keeping them equidistant above, as well as below, take four bars of Wood, about three inches broad, and one inch thick, and nail them round about upon the four sides, on each side one, so that  
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being nailed on *Horizontally*, they may make *right angles*, with the tops of the standards above. There are then for distinctions cause, the North-bar, and the South-bar, that runs East and West, and the East-bar, and the West-bar, that runs South and North. There is here no difficulty in the thing it self, but only in the fancy to conceive it. Besides these four, there must be other four of the same form and fashion, nailed on 'arder down about the middle of the four standards. Take next some small Brass Wyre strings, such as are used in *Virginals*, and fix one from the middle of the South-bar, that's upmost, to the middle of the South-bar just under it. Fix it so, that it may be exactly Perpendicular, which may be done, with a great weight of Lead. Take a second Wyre string, and hang it plumb from the West end of the North-bar, and another from the East end of the same Bar, I mean the Bar that's nearest to the top. These three strings so fixed, will go near to make an *equilateral triangle*.

Now because the device is for finding out the *Meridian* by the Stars in the night time, not by any indifferently, but by these that are nearest to the *Pole*, therefore observe in *July* and *August*, when the *Guard-stars* in the evening begin to come down towards the West, and keeping clost one eye, bring the other somewhat near to the South-most string, and order your sight so, that this string, and the West-most string upon the North side, may catch the foremost *Guard-star* in the down-coming, when it is furthest West, and there fix it: When the same Star is turning up towards the East, catch it by the South-most string, and the East-most string on the North side, and your work is done, if so be, you divide exactly, between the East-most and West-most, and there hang a fourth string, which  
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with the string upon the South-side, gives you the true South and North. For better understanding, note first, that, when the *Guard-stars* are coming down, or going up, the *Altitude* varies quickly, but the *Azimuth*, or motion from East to West, will not vary sometimes sensibly in two hours almost, which is a great advantage in this case. But when you find out the *Meridian* with a *Plain*, and a Perpendicular *Stylus*, by the shadow of the *Sun*, if it be not when he is about East and West, the *Azimuth* alters more than the *Altitude*, which is a great disadvantage. Now its certain, the slower the motion be from East to West of any *Star*, it is the easier to observe, and it is the more sure way. Note secondly, that special care must be had, to cause the strings hang Perpendicular. Note thirdly, that before you begin your Observations, the South-most string must be made immoveable, but the East-most, and West-most, on the other side, must not be so, because as the *Stars* in going about move from East to West, so must the said two strings be left at liberty, to move a little hither and thither, till the Observations be ended. Note fourthly, that as soon as you perceive sensibly, the foremost *Guard-star* to decline towards the West, then you must begin to observe, which is nothing else, but to fix your eye so, that the South-most and West-most string, may cover the said *Star*. And because in coming down, it goes West, therefore, let the West-most string move towards the left hand by degrees, following the *Star* to its utmost, till it be covered by them both. Follow the same method, in observing the same *Star* in going up towards the East. Note fifthly, that when you make the two strings cover the *Star*, that which is nearest to the eye, will appear transparent, and of a larger size, so that you may perceive distinctly  
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thorow it, not only the Star it self, but the other string also, which is a great advantage. This is evident to any, who holds a bended silk threed between their eye and a Star in the night time; for when you direct your sight to the Star, the string appears like the small string of a *Virginal* when it trembles. Note sixthly, that in observing in a dark night, you must have a *Cut-throat*, that by the light of the candle you may perceive the strings. Some other things might be noted, but you will find them better by experience, than they can be exprest here.

I named *July* and *August* in the evening for observing the *Guard-stars*, when they are West-most, but there are several other seasons, when this may be done as conveniently. They are East-most in the latter end of *October*, and beginning of *November* about 5 or 6 a clock in the morning. If a man were desirous to make this observation quickly, I suppose he might in the end of *October*, find the said stars West-most in the evening, and East-most the next morning. Besides the *Guard-stars*, a man may make use of the *Polar-star*; for as it goes higher, and lower than the true *Pole*, by 2 degrees and 26 minuts, so it goes as much to the East, and as much to the West, once in 24 hours. In the end of *July*, you will find the *Polar-star* East-most, about 9 a clock at night, and in the end of *January* West-most at 9 a clock. Note, that every month, the fixed stars come sooner to the same place by two hours: therefore in the end of *August* the *Polar-star* must be West, at 7 a clock at night, and East at 7 a clock in the morning. When the *Meridian* is found out after this manner, there is no *Star* or *Planet* can pass it, but you may know exactly when, be it never so high, or never so low. For there is nothing to be done, but to wait, till the South-most and North-most



most string cover the body of the *Star*. If it be the Sun, hold up a white Paper, behind the two strings, and when their shadows do co-incide, and are united, then is his Center in the *Meridian*. If the Sun do not shine clear, as when he is under mist, or a thin cloud, you may exactly take him up in the *Meridian*, with the two strings. This Frame will serve as well, to know when any of the North Stars comes South, or North, and consequently when they are highest, and when they are lowest: for being fixed in an open place of the *Orchard*, there's no *Celestial Body* can pass the *Meridian*, either on the one side, or the other, but it may be catched, what ever the Altitude be, and that most easily.

## OBSERVATION VIII.

There hath been much inquiry made by some anent the reason, why the dead body of a man or beast, riseth from the ground of a Water, after it hath been there three or four days. But though many have endeavoured to solve the question, yet the difficulty remains; and in effect it cannot be answered, without the knowledge of the foregoing Doctrine, anent the nature of fluid Bodies. To find out the reason then of this *Phenomenon*, consider, that all Bodies, are either naturally heavier then Water, as Stone and Lead, or naturally lighter, as Wood and Timber. If they be heavier, they sink: if they be lighter, they swim. Now I say, a mans body immediatly after he is drowned, his belly being full of Water, must go to the ground, because in this case, it will be found *specifically* or *naturally* heavier then Water. That's to say, a mans body, will be heavier, than as much Water, as is the

the bulk of a mans body. For pleasing the fancy, imagine a Statue to be composed of Water, with all the true dimensions of the person that's dead, so that the one shall answer most exactly to all the dimensions of the other. In this case, if you counterpoise them in a Ballance, the real body, that's made up of Flesh, blood, and bones, shall weigh down the other. But after this dead body hath lien a short time among the Water, it presently begins to swell, which is caused by the fermentation of the humors of the blood, which goeth before putrefaction, and after three or four dayes swells so great, that in effect, it becomes naturally lighter than Water, and therefore riseth. That is to say, take that body, that is now swelled, and as much bulk of Water, as will be the precise quantity of it, and having counterpoised them in a Ballance, you will find the Water heavier than the body.

## OBSERVATION IX.

**U**Pon *Thursday* the 25 of *August* 1670, the following Experiment was made in a new *Coal-sink*, on the West side of *Trarant*. When the *Coal-bewers* had digged down about 6 or 7 fathom, they were interrupted sometimes with *ill Air*: therefore to know the power and force of the *Damp*, we let down within the Bucket a *Dog*. When he had gone down about 4 fathom, or middle Sink, we found little or no alteration in him, save only that he opened his mouth, and had some difficulty in breathing, which we perceived evidently: for no sooner he was pulled up to the top, where the *good Air* was, but he left off his gaping. We let him down next to the bottom, where he tarried a pretty while, but no more change we found in

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him than before. After this we let down a great quantity of *Whins*, well kindled with a bold flame, but they no sooner came to the middle of the *sink*, but the flame was in an instant extinguished: and no sooner was the Bucket pulled up, but they took fire again. This was 5 or 6 times tried, with the same success. If we compare this Observation with the first, we will find, that all *Damps* are not of the same power and force, but that some are stronger, and kills men and beasts in an instant: and that others are less efficacious, and more feeble, and doth not so much hurt, and that men may hazard to go down into a *Sink*, where *ill Air* is, even though fire be sometimes extinguished. We see next, that these *Damps* doth not always infect the whole Air of a *Coal-pit*, but only a certain quantity: for sometimes it is found in the bottom, sometimes in the middle. And we see lastly, that they are not always of long continuance: for it is found, that though the Air be ill in the morning, yet it may be good ere night; and totally vanished ere the next day. We may add, as was noted in the first Observation, that these *Damps* depend much upon the situation of the winds, being in strong Southerly winds, they are frequently in these places.

## O B S E R V A T I O N X.

OF these many excellent devices, that have been found out of late, the *Air-pump* is one, first invented in *Germany*, and afterwards much perfected in *England* by that Honourable Person Mr *Boyl*, who for his pains, and industry in making Experiments therewith, deserves the thanks of all learned persons. Several trials hath been made of late by it, some whereof, are as follows. I took a slender  
Glass;

Glass-tub about 40 inches long, clos'd above, and open below, and filled it with VVater. I next inverted it, and set the orifice of it, just upon the mouth of the Brass-pipe, that bends upward thorow the board, whereon the *Receiver* useth to stand, and cemented them together. At the first exsuction, the whole VVater in the Pipe fell down, and ran thorow the *Brass-conduit* to the Pump. Having for a short while stopped the passage, and thrust down the *Sucker*, I next opened it again, and the *Pump* being full of VVater, it was driven with a considerable force up thorow the Pipe; yet was it not compleatly fill'd as before, by reason of some Air, that I saw in the top. After this was done, with pleasure five or six times, I opened the *Stop-cock* more quickly, than I had used, but the VVater, by this means, was so furiously driven up thorow the Tub, that in effect, it broke the end of it, that was *Hermetically sealed*; and the piece that flew off, did hit the ceiling so smartly, that it rebounded a very far way. From this we see the reason, why VVater falls not down from Vessels that have narrow necks, though they be inverted, because it's kept in by the force and power of the environing Air. 'Tis observable, that though this Pipe had been 30 foot high, yet the whole VVater in it would have subsided, and fallen down, with one exsuction.

The next trial was with the help of a small *Receiver*, which in effect was a real *Cupping-glass*. This had a hole made in the bottom of it, and was cemented to the *Brass-plate*, and the mouth of it looking upward, had a lid for covering of it. I took next the lately mentioned Glass-pipe, and filled it with good *Brandy*, and having drowned the end of it among stagnant *Brandy*, I set the Vessel wherein it was within the *Receiver*, the Pipe coming up thorow

the lid, and having cemented it closely, I made the first exsuction, and found no descent of the Liquor from the top of the Tub. At the second, it fell down about an inch. At the third, it fell down four or five. But here appeared a great multitude of small Bubbles of Air, like broken VVater, near the top of the Pipe within. And besides this *Phænomenon*, there ascended from the stagnant Liquor up thorow the Pipe, an infinit number of small Bubbles, no bigger than Pin-heads, for a very large time. VVith a fourth exsuction, it fell down within two or three inches of the *stagnant Brandy*. And thinking to make the one level with the other, I made a fifth, but here appeared a strang effect, namely, not only the whole *Brandy* in the Pipe subsided, and was mingled with the *stagnant Brandy*, but at this exsuction, there came a great quantity of Air from the mouth of the Pipe, and rose up thorow the *stagnant Liquor* in Bubbles. Having made another exsuction, there came yet more Air out, and so copiously, that I thought there had been some leak in the Tub, through which the outward Air had entered; but knowing the contrary, I continued Pumping a very long time, till I found less and less come out, and at length, after near 30 exsuctions it ceased. This Air to appearance, was so much as might have filled twenty Tubs, every one of them as large, as the Tub it came out of. And surely all of it came out from among the small quantity of *Brandy* that filled the Pipe, and that environed the mouth of it, I mean the *stagnant Brandy*, both which would not have been eight spoonful. After this I opened the *Stop-cock* leasurably to let in the Air to the *Receiver*; then did the *Brandy* climb up the Pipe slowly, till it came near to the top, and there made some little halt, by reason of half an inch of Air that appeared

peared there. But more and more Air coming into the *Receiver*, that half inch in the top of the Pipe, did so diminish, that it appeared no bigger than the point of a Pin, and was scarcely discernable to the eyes. What a strange and wonderful faculty of dilatation and contraction must be in the Air, seeing that which presently had filled the whole Tub, that was 40 inches long, and the sixth part of an inch wide, was contracted to as little room, as the point of a Needle. And by making some new exsuctions, that small *Atom* of Air did so dilate it self again, that it filled the same Tub, and not only that, but, as formerly, it bubbled out from the mouth of the Pipe several times.

'Tis to be observed, that though at the first falling down of the *Brandy*, it appeared like broken Water, near the top of the Pipe within, yet no such thing was seen the second time it fell down; the reason is, because by the first exsuctions, it was well exhausted of its *aërial particles*. Once or twice I found, after the *Brandy* within the Pipe was well freed of Air, that no exsuctions could make it move from the top of the Tub; and observed a round Bubble of Air to march up, which when once it came to the top, did separate the one from the other. If this hold good, it seems to prove, that neither Mercury, nor any other Liquor would fall down in Pipes, unless there were Air lurking amongst the parts to fill up the deserted space.

From this Experiment we learn, that no person can well apprehend or conceive, how far, and to what bounds the smallest part of Air is able to expand it self. And it proves evidently, that when the *Receiver* is as much emptied as it can be, by the Art of man, yet it is full of Air completely.

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The third trial was after this manner: I set within the *Receiver* a little Glass half full of *Brandy*, and the lid being cemented on, I began to pump, but there appeared no alteration at the first exsuction. At the second, I perceived a great company of very small Bubbles, that for a long time ascended from the body of it, and came to the surface. At the third, they were so frequent, and great, that the *Brandy* appeared to seeth and boil, and by reason of the great ebullitions, much of it ran over the lips of the Glass, and fell into the bottom of the *Receiver*. This boiling continued for the space of 7 or 8 exsuctions, and by process of time, the Bubbles grew fewer and fewer, and when about 30 or 40 exsuctions were made, no more appeared. With this same sort of *Brandy*, I filled the fore-named Pipe, and set it within the *Receiver*, the mouth of the Tub being guarded with the same sort of Liquor. When it began to subside, there appeared no Bubbles near the top as before: the reason seems to be, because the *Brandy* was well exhausted from its *aërial particles*. For a fourth trial, I filled the same Tub with Ale, that was only 5 or 6 dayes old, and drowning the end of it among stagnant Ale of the same kind, I began to Pump, and found, that as soon as the Liquor began to subside, from the top of the Pipe, the whole Ale within the Pipe, almost turned into Air, and Froth, and so many large Bubbles came up from the stagnant Liquor, that I thought the whole was converted into Air. It was most pleasant to behold their several forms and shapes, their order and motion. This same Tub being filled with *sweet milk*, I found very few Bubbles in it, when by the exsuctions, it began to subside. I likewise took a little Glass-viol, and fill'd the half of it full with common Ale, and set it within the *Receiver*. At the first exsuction, Bubbles

Bubbles of Air began to rise out of it. At the second and third, they did so multiply, that they fill'd the other half of the Glass, and ran over, as a Pot doth when it boileth. And before I could exhaust all the Air out of it, more than 20 exsuctions passed.

For a fifth trial, I filled the often mentioned Pipe with Fountain-water, and when it began to subside by Pumping, I found it leave much Air behind it. But all the exsuctions I made, could not make the Water of the Pipe go so low, as the stagnant Water, by which impediment, I could Pump no Air out of the Pipe, as I did, while I made use of *Brandy*. This tells us, that either there is not so much Air lurking among *Water*, as among *Brandy*, or that the Air among this, hath a more expansive faculty in it, than the Air that lurks among *Water*. If any think, that it is not true and real Air, which comes from the *Brandy*, but rather the *Spirits* of it, which evaporate. I answer, if a man tast this *Brandy* that's exhausted of its *aërial particles*, he will find it as strong, as before, which could not be, if the *Spirits* were gone.

For a sixth trial, I took a *Frog* and inclosed her within the *Receiver*. But all the exsuctions I was able to make, could not so much as trouble her. Only, when the *Receiver* was exhausted, I perceived her sides to swell very big, and when the *Stop-cock* was turned, to let in the Air again, her sides clapped close together. I observed likewise, when the Air was pretty well Pumped out, that the *Frog* had no respirations, or if there were any, they were very insensible. The next day, after she had been prisoner in the *Receiver* 24 hours; I began again to Pump, and after several exsuctions, her sides swell'd pretty great, and I perceived her open her mouth wide, and somewhat like a  
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Bag endeavouring to come out, which surely hath been some of her noble parts, striving to dilate themselves, the body being freed of all Pressure from the ambient Air.

## OBSERVATION XI.

**T**AKE a slender chord, about 4 or 5 yards in length, and fasten the middle of it to the ceiling of a Room with a nail, so that the two ends of it may hang down equally. Take next a piece of Wood, two or three foot long, two inches broad, and one inch thick, and boring an hole in each end of it, put through the two ends of the chord, and fasten them with knots; but so, that the piece of Wood may ly Horizontal, and be in a manner a *Pendulum* to swing from the one end of the Chamber to the other. Take next a Bullet of Lead or Iron, about 20 or 24 ounces, and lay it upon the said piece of Wood: but because it cannot well ly, without falling off, therefore nail upon the ends, and the sides of the Timber, four pieces of Sticks, on each end one, and on each side one, as *Ledgers*, for keeping the Bullet from falling off. All things being thus ordered, draw up the piece of Wood towards the one side of the Room, by which means losing its horizontal position, it will ly declining-wise, like the roof of an house. In this position, lay the Iron Bullet in the upmost end of it, and then let them both pass from your fingers, the one end of the Wood going foremost, and you will find it swing towards the other side of the house, and return again, as a *Pendulum*. This motion, if the Wood be well guided in its vibrations, will last perpetually, because in its moving down, the Bullet is hurled from the one end of the Wood, to the other, and hits it so smartly, that it begets in it,

an impulse, whereby it is carried farder up, than it would be, without it. By this means, the *vibrations* get not liberty to diminish, but all of them are kept of the same length. In the second vibration, the same Bullet is hurred back again to the other end, and hiting it with all its weight, creates a second impulse, wherewith the Wood is carried, as far up as the point it was first demitted from.

Though this may seem a pretty device to please the fancy, that's many times deceived, while things are presented to it, by way of speculation, yet upon tryal and experience, there will be found, an unspeakeable difficulty: and it's such an one, that a man would not readily think upon. I said, that when the Wood was let go, and was in passing down, the Bullet in it, would hurl down, and hit the oppsite end, and beget an impulse; but there is no such thing, for verily, though the Bullet be laid upon a very declining plain Board, whereupon no man could imagine a round body could ly, yet all the time the Board is in swinging, from the one side of the Chamber, to the other, and consequently, sometimes under an horizontal, and somtimes under an declining position, the Bullet lies dead in the place, where you first placed it. This Observation is not so much for a perpetual motion, as for finding out the reason of this pretty *Phenomenon*, namely, what's the cause, why the Bullet, that cannot ly upon a reclining Board, while it's without motion, shall now ly upon it, while it's under motion? What is more difficult, and nice, to ly upon any thing, that declines from a levell, than *Quick-silver*; yet lay never so much of it upon this Board, while it is swinging, it shall ly dead, and without motion. But no sooner you stop the motion of the wood,

but assoon, the Bullet, or the *Quick-silver*, is hurled, either this way, or that way.

## OBSERVATION XII.

**I** Find it mentioned by some learned persons, that when a Ship is under Sail, if a stone be demitted from the top of the Mast, it will move down in a line parallel with it, and fall at the root. Some might think, it ought not to fall directly above the place it hang over, but rather some distance behind, seing the Ship hath advanced so much bounds, in the time, wherein the stone is coming down. Likewise, while a Ship is under Sail, let a man throw up a stone never so high, and never so perpendicular, as to his apprehension, yet it will fall down directly upon his head again, notwithstanding that the Ship hath run (perhaps) her own length in the time, while the stone was ascending and descending. This experiment I find to hold true, which may be easily tryed, especially when a man is carried in a Boat upon smooth Water, drawn by a horse, as is done in some places abroad. Let him therefore throw up a little Stone, or any heavy Body, and he will find it descend just upon his head, notwithstanding that the Horse that drags the Boat, be under a gallop, and by this means hath advanced ten or twelve paces in the time. Or while the Boat is thus running, let a man throw a stone towards the brink of the VVater, in this case he shall not hit the place he aimed at, but some other place more forward! This lets us see, that when a Gun is fired in a Ship under Sail, the Bullet cannot hit the place it was directed to. Neither can a man riding with a full Career, and shooting a Pistol, hit the person he aims at, but must surely miss him,

him, notwithstanding, that though in the very instant of time wherein he fires, the mouth of the Pistol was most justly directed. For remedy whereof, allowance must be granted in the aiming at the mark.

While a man throws up a stone in a Ship under Sail, it must receive two distinct impulses, one from the hand, whereby it is carried upward, the other from the Ship, whereby it is carried forward. By this means, the stone in going up, and coming down, cannot describe a perpendicular, but a crooked Line, either a *Parabola*, or a Line very like unto it. Neither can it describe a perpendicular Line, in coming down from the top of the Mast, though in appearance it seem to do so, but a crooked one, which in effect must be the half of that, which it describes in going up, and coming down. For this same cause, a stone thrown *horizontally*, or towards the brink of the VVater, must describe a crooked Line also. And a *Pistol Bullet* shot, while a man is riding at a full *Carreer*, must describe a Line of the same kind. Note, that a man walking from the *Stern* of a Ship to the *Head*, walks a longer way, than in walking from the *Head* to the *Stern*. Secondly, a man may walk from the *Head* to the *Stern*, and yet not change his place. 'Tis observable, that a man *under board*, will not perceive whether the Ship be sailing, or not, and cannot know when her *Head* goes about. And it is strange, that when a man is inclosed in a *Hogs-head*, though he have light with him, yet let him be never so oft whirled about, he shall not know, whether he be going about, or not.



## OBSERVATION XIII.

I Found in a *Philosophical transaction* lately Printed, that Decemb. 13. 1669, one Doctor Beal found the Mercury in the *Baroscope*, never to be so high, as it was then. That same very day, I found the hight of it 29 inches, and nine ten parts, which I never observed before. And though the day here was dark, and the Heavens covered with Clouds, yet no rain for many dayes followed, but much dryness, and fair weather. On *Saturday* night, *March* 26, 1670, I found the altitude no more than 27, and nine ten parts. This night was exceeding windy, with a great rain. On *February* 1. 1671. I found the altitude 30 inches, and the Heavens most clear. But in the most part of *May* following, I have found the hight but 27 inches, and five ten parts, in which time there was abundance of rain.

## OBSERVATION XIV.

November 7. 1670. I made exact trial, with the *Magnetick Needle* for knowing the variation, and I found it vary from the *North*, three degrees and a half, towards the *West*. *Hevelius* writes from *Dantzick* to the *Royal Society* at *London*, *July* 5. 1670. that it varies with him seven degrees twenty minuts, west.

## OBSERVATION XV.

December. 17. 1669, I observed with a large *Quadrant*, half 9 a clock at night, the formost *Guard-star*, when it was in the *Meridian*, and lowest, to have 41 degrees

grees 22 minuts of altitude. And on *January 7. 1670* at 7 a clock in the morning, I found it, when it was in the *Meridian*, and highest, to have 70 degrees, 27 minuts. Hence I conclude the *elevation of the Pole* here to be 55 degrees, 54 minuts, 30 seconds: and consequently as much at *Edinburgh*; because both the places are upon one and the same Parallel.

## OBSERVATION XVI.

FOR finding the true *Meridian*, follow this method. In some convenient place fix two Wyre strings with weights at them, that they may hang perpendicular. Then in the night time, observe, when the *fourth star of the Plough* begins to come near to the lowest part of the *Meridian*, at which time you will find the *Polar star* highest. Then, so order the two strings, by moving them hither, and thither, till both of them cover both the said *Stars*, then shall they in that position give you the true *South* and *North*. This observation is the product of the seventh.

## OBSERVATION XVII.

THere fell out in *Mid and East-Lothian*, on *Thursday May 11, 1671*, in the afternoon, a considerable shower of hail, with thunder and rain. It came from the South-west, with a great blast of wind, and ran alongs from *Piſts-land-hills* North-east, towards the Sea-coast. The hail were big in several places, as *Musquet Ball*, and many of them rather oval than round. Some persons suffered great loss of their *young Pease*; others of their *Glass Windows*. Eight or ten days before, there was a considerable hear,  
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and dry VVeather. For 20 days after, cold Easterly winds, with rain every day, but especially, in the end of the Moneth, extraordinary rain and mist. This is so much the more to be observed, because in this Countrey, seldom such extraordinary *hail* falls out. This year the *Agues* and *Trembling Fevers* have been most frequent, and to many deadly.

## OBSERVATION XVIII.

I Did hear lately of a curious Experiment in *Germany*, made by a Person of note, which I shall briefly in this Observation, let the *Reader* understand. And though I have heard since, that it is now published in Print, yet I hope it will not be impertinent to mention it here, especially for their cause, who cannot conveniently come to the knowledge of such things. And for this reason also, that I may explicat the *Phenomena* thereof, from the foregoing doctrine, and demonstrat particularly the true cause of that admirable effect, that's seen in it, which I desiderat in the publisher. The Auctor then takes two *Vessels* of *Brass*, each one of them in form of half a sphere, of a pretty large size. Nothing can more fitly represent them for form and quantity, than two *Bee-skeps*. Only, each of them, hath a strong *Ring* of *Brass* upon the *Center* without: and they are so contrived by the *Artist*, that their orifices agree most exactly, so that when they are united, they represent an intire Sphere almost. In one of the sides, there's a hole, and a *Brass Spigot* in it, through which the whole *Air* within, is exsucted, and drawn out, namely by the help of the *Air-pump*. And, when by several exsuctions the *Vessels* are made empty, the *Stop-cock* is turned about,

about, by which means, no *Air* can come in. And, they remaining empty, are taken from the *Pump*, and do cleave so fast together, that though a number of *lusty fellows*, 12 on each side, do pull vigorously, by help of ropes fastned to the *Rings*, yet are they not able to pull them asunder. And because this will not do it, he yokes in 12 *Coach Horses*, six on every side, yet are they not sufficient, though they pull contrariwise to other, to make a separation. But to let the *Spectators* see, that they may be pulled asunder, he yokes in 9 or 10 on every side, and then after much whipping, and sweating, they pull the one from the other.

The cause of this admirable effect, is not the fear of *vacuity*, as some do fancy, for if that were, all the *Horses* in *Germany* would not pull them asunder, no not the strength of *Angels*. It must then be some extrinsick weight and force, that keeps them together, which can be nothing else, but the weight of the *invirning Air*. Because, no sooner a force is applied, that's more powerful, than the weight of the *Air*, but assoon they come asunder. And so neither six men, nor six horses on each side are able to do it: but nine or ten on each side makes a separation. For understanding the true cause of this *Phenomenon*, we must consider that the *Vessels* are 18 inches in *diameter*. If this be, then according to the last Experiment, there are two Pillars of *Air*, each one of them as heavy as a Pillar of *Mercury* 18 inches thick, and 29 inches long, by which they are united. Or, each Pillar of *Air*, is as heavy, as a Pillar of *Water* 34 foot high, and 18 inches in *diameter*. For finding the weight of it in pounds, and consequently, the weight of each Pillar of *Air*, by which the two *Vessels* are united, follow this method, First, multiply 9 the semi-diameter

diameter of the *Pillar*, by 54 the circumference, and this gives you 486, the half whereof is the bounds of the *Area*, namely 243. And because 34 foot contains 408 inches, I multiply 408 by 243, the product whereof is 99144; so many square inches are in a *Pillar* of *Water* 34 foot high, and 18 inches thick. Now seeing there are 1728 inches in a *cubical foot*, I divide the number 99144, by this number, and I find 57 square foot of *Water*, and more. And because every square foot weighs 56 pound *Trois*, I multiply 56 by the number 57, and the product is 3192 pound, which is the just weight of a *Pillar* of *Water* 34 foot high, and 18 inches in diameter, and which is the just weight also of each *Pillar* of *Air*, by which the two *Vessels* are kept together, which will be more weight than *seven Hogs-heads full of Water*. This is easily known, for seeing a quart of our measure weighs seven pound, (or to speak strictly six pound fourteen ounces, seeing the *Standard-jug* of *Striviling* contains three pound seven ounces of *Water*) a gallon must weigh 28 pound: but 16 times 28, is 448. A *Puncheon* then full of *Water*, weighs 448 pound. If then you divide 3192 by 448, you will find more than 7. The 9 horses then upon this side have 3192 pound weight to draw, or 199 stone, or the weight of *seven Hogs-heads full of Water*. The other 9 horses upon the other side, have as much to pull. 'Tis no wonder then to see so much difficulty and pains to make a separation. It is observed, that before the *Air* be exsucted and drawn out of the two *Vessels*, one man is able to pull them asunder with his hands only. Nay, which is more, if he but blow into them, as a man doth into a Bladder, he will separat them. The reason is, because the *Air* within, is of as great force, as the *Air* without. 'Tis observable next, that the larger the *Vessels* be  
in

in *diameter*, the more strength is required to pull the one from the other. Upon supposition then, they were 4 foot wide, I verily believe 30 yoke of oxen, upon every side, would hardly disjoyn them; because the weight of each Pillar of Air, would be no less, than 22844 pound, which would take 63 strong horses to overcome the force of it. To pull the one *Vessel* therefore from the other, there must be 126 horses, that is, 63 on every side.

## OBSERVATION XIX.

**T**Hough this Observation may seem useles, because the Proposals, that are mentioned in it, cannot be made out, and brought to pass, the *Author* having died, before he had encouragment to prosecute them: yet for these following reasons, I have adventured to insert it here. First, that others, may either be minded to find out (if possible) his inventions, or set a work to find out somethings, that may be as useful. Next, because, he was one of this same *Nation*, and a great *Master* of the *Mathematicks*, not only in the *Speculative*, but in the *Practical* part chiefly, and admirable for invention. And for this cause principally I have presumed to mention his designs, and proposals, which were found among his *Notes*, after his death, which are here insert, as they were written with his own hand, and offered to the publick, not only at home, but abroad to strangers. There have been men in all ages famous, for some one Art and Science beyond others, as *Apelles* for Painting, *Hippocrates* for Medicine, *Demosthenes* for Oratory, but who have been more famous in their time than some persons for their profound knowledge in *Astronomy*, *Geometry*, and the other parts of the *Mathematicks*. What



an admirable person was *Archimedes* for his divine knowledge, both in the *Speculative*, and *Practical* part. Yet, it was not his speculations simply, though excellent, that did so much commend him, as his *Inventions*, and admirable *Engines* for peace and war, as is clear from the *Roman Histories*, and others. I confess the Students of these Arts, are not so much in request now, at least amongst some, and that knowledge is not so much esteemed; and the reason may be; because some who profess themselves *great Masters*, study nothing but the pure speculations, which sometimes are to small purpose, others before knowing the same, unless for perfecting of the mind, and giving to a man some private satisfaction. But such things will never commend a man so much as the practical part, and new Invention will do. 'Tis surely a small business for one to do nothing, but to nibble at some petty Demonstration. But when such speculations are joyned with invention and practice, for the profit, and use of men, among whom they live, then are they far more to be commended. And if this be not, such knowledge is of small advantage to themselves or others. Many of the Ancient, and late Astronomers have been, and are famous for practice, as witness the indefatigable pains they have been at in making their Observations. What hath so highly commended *Merchiston* over all *Europe*, as his inventions, especially his *Logarithmes*? And if all be true, that's reported (which I am apt to believe) he might have been more renowned, for his many excellent *Engines*, which though useful, yet because hurtful to mankind, he buried with himself. I am confident, if the Author of these proposals had had time to have prosecuted them, he would have been celebrated in the Catalogue of the most famous *Mathematicians* of his time. But leaving this, I shall

shall give you them in his own words: but first his Apology.

These bold proposals will need perhaps an apology to such, to whom the causes, and circumstances are unknown. Let it suffice, that the Proposer finding himself between two extreams, either to leave unprosecuted this affair, for fear of being mistaken by some, as impudent, or to commit himself openly to the charitable judgement of others, who will suspend their censure, till they have seen what his endeavours will produce. He hath rather chosen this last, especially considering, that his silence could not answer to his duty, which he owes to his Countreys service, seeing the following Engines may be so useful to it. A deduction of the fabrick, causes, and occasions of these *new Engines*, that set the Inventer a-work, would take a long time to discourse upon. This Paper therefore is only destined for a short information of their use, the rest, which could not here be insert without impertinency, may be supplied afterwards (if need be) either by a discourse, or by a particular demonstration. The Proposer then is of opinion, (if self-love of his own Inventions do not blind his Judgement) that these *paradoxes* may be truly affirmed.

That if it shall please His Majesty to arm with these new Arms, and Engines, 500<sup>00</sup> Foot, or fewer, this small number shall be Masters of the Fields in *France, Germany, Spain*, or where else it shall please His Majesty, however encountered by the most powerful Army of Horse or Foot, armed with ordinary Arms, of Pistol, Carabine, Pike, Musquet, which Europe can bring to the Fields.

The cause of this admirable effect, is in the quality of these new Arms, by which, the whole Horsemen and Footmen of the enemy are rendred useless, and unservicable;

neither can they do any offence to these, who are so armed.

The *Musquetteers*, who can only serve against these *Machins*, shall be put to such disadvantage, as it is impossible they can stand, the least time, in the common way of service with the *Musquet*, it not being able to make one shot for twenty, which shall be made from these new Engines.

These *new Arms*, have this advantage likewise, that these who are so armed, can by no force of Horse or Foot be broken, or put to disorder. The Souldiers are also by them put to a necessity of keeping together, and fighting, and by them, they are so *Baricado'd*, and strongly defended, that if they leave them not, they cannot be exposed to danger. This contributes much to good Discipline, when the Souldiers shall by necessity be tied to his duty, and fear, which otherwise makes him run away, shall here for his safety make him stand.

These *new Arms* are useful, as well in Marching, as in Combating, for with them, we may march securely two in front, through the straitest passages, and be able to force with them any advantage a strait passage can give to an enemy. Besides, for a long hasty march, where Victuals cannot be well carried, the Souldiers are able with these *Arms* to carry their own provision for eight dayes, with more facility, then they can now carry one dayes provision.

To lodge in the open fields, these *Arms* shall need no Intrenching, for they sufficiently both Arm and *Baricade* the Souldiers.

And as they are useful in Service, so are they a great deal cheaper than the ordinary *Arms*. For although with 5 thousand men so armed, the service of 100000 armed with common Arms may be done, yet the whole price of them

them will not amount to that which will be required for arming 20500 *Corrassiers*, as may be particularly deduced, from the particular prices of the Arms, and Engines fitted for the service of 5000 men. The Proposer doth offer to shew, that these Arms will not surmount 40000 pound *Sterling*. The *Artillery* will amount to 4500, and the payments of this number of men so armed, yearly to 70000 pound. Yet all these are taken in so large a latitude of reckoning, as the sum of *Arms*, *Artillery*, and payments, will not be much above 130000 pound *Sterling*.

The Arms from which this effect is promised, are *new Engines*, with which one man is able to do the service of a great many *Musquetteers*. And those are of two sorts, either to be used upon a small Wagon for Footmen, or on a greater for a Horse, with either of which, one hand is able to make the fire of 100 *Musquetteers*, and so much better, by how much it is more regularly, and fitly done for execution and offence. The new Cannon shall have the like advantage above the old, both for easie carriage, being lighter, and for greater execution, shooting six, nine, or twelve Bullets for one. These Arms give not only this advantage at Land in the field, but also in Ships, and places of defence.

These nine following propositions he likewise offered to make good,

First, With one shot of *Cannon*; to do the execution of five shot of the same *Cannon*, in the common way of Battery.

Secondly, to disable any Ship or Galley with one shot of *Cannon*.

Thirdly, to fire any combustible matter with the shot of a *Cannon*.

Fourthly,

Fourthly, to make an *Machin* or *Engine* for transporting an Army, which may be carried without the incommodity thereof.

Fifthly, to make a floating *Fortress* for defence of Rivers, and prohibition of Passages.

Sixthly, to make a *Mortar* that hath a *directory Stell* upon the Carriage.

Seventhly, to make *Petards* of divers forms, that shall be able to do twice as much execution, as those that contain as much Powder.

Eighthly, to make small *Petards* of great effect.

Lastly, to make *Bridges*, and *Scaling Ladders* of easie Carriage.

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#### OBSERVATION XX:

THESE Observations being *Miscellany*, require not a formal connexion between themselves, and therefore 'tis no matter what method I keep in setting them down. And though this may seem not so pertinent, as others, yet because the design of it is only *Philosophical*, and for advancing the *Historical* part of Learning in order to *Spirits*, upon which the *Scientificall* part doth so much depend, I have presumed to insert it here, considering also that there are some, who have adventured to deny their existence, and being; which from such a History as this, may be more than probably evicted. I find likewise, that several Writers have remarked such strange accidents, and have transmitted them to posterity, which may serve for good use. The subject-matter then of this Observation, is a true and short account of a remarkable trial, wherewith the Family of one *Gilbert Compbel*, by Profession a Wea-

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ver in the old Paroch of *Glenluce* in *Galloway*, was exercised. Though the matter be well known to several persons at that time, and since too; yet there are others, eighteen years intervening, to whom (perhaps) such a relation will not be unacceptable, who have either not as yet heard of it, or at least, have not gotten the true information, which is here set down, as it was Written, at the desire of a special Friend, by *Gilbert Campbel's* own Son, who knew exactly the matter, and all the circumstances, whose words are as follows.

It happened in *October 1654*, that after one *Alexander Agnew*, a bold and sturdy Beggar, who afterwards was hanged at *Dumfreis* for blasphemy, had threatned hurt to the Family, because he had not gotten such an alms as he required: the said *Gilbert* was oftentimes hindered in the exercise of his Calling, all his Working-Instruments being some of them broken, some of them cutted, and yet could not know by what means this hurt was done; which piece of trouble did continue, till about the middle of *November*, at which time the Devil came with new and extraordinary assaults, by throwing of Stones in at Doors and Windows, and down thorow the Chimney-head, which were of great quantity, and thrown with great force, yet by *God's* good providence, there was not one person of the Family hurt, or suffered dammage thereby. This piece of new and sore trouble, did necessitat Mr. *Campbel* to reveal that to the *Minister* of the Paroch, and to some other Neighbours and Friends, which hitherto he had endured secretly. Yet notwithstanding of this, his trouble was enlarged; for not long after, he found oftentimes his Warp and Threeds cut, as with a pair of Sizzers, and the *Reed* broken: and not only this, but their apparel cut af-

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ter the same manner, even while they were wearing them, their Coats, Bonnets, Hose, Shooes, but could not discern how, or by what mean. Only it pleased *God* to preserve their persons, that the least harm was not done. Yet, in the night time, they wanted liberty to sleep, something coming, and pulling their Bed-cloaths and Linnings off them, and leaving their bodies naked. Next, their Chests, and Trunks were opened, and all things in them strawed here and there. Likewise, the parts of the Working Instruments, that had escaped, were carried away, and hid in holes and bores of the house, where hardly they could be found again. Nay, what-ever piece of Cloath, or Household-stuff, was in any part of the house, it was carried away, and so cut and abused, that the Good-man was necessitated with all haste and speed, to remove, and to transport the rest to a Neighbours house, and he himself compelled to quite the exercise of his Calling, whereby only he maintained his Family. Yet, he resolved to remain in the house for a season. During which time, some persons about, not very judicious, counselled him to send his children out of the Family, here and there, to try whom the trouble did most follow; assuring him, that this trouble was not against all the Family, but against some one person, or other in it, whom he too willingly obeyed. Yet, for the space of four or five dayes after, there were no remarkable assaults, as before. The Minister hearing thereof, shewed him the evil of such a course, and assured him, that if he repented not, and called back his children, he might not expect that his trouble would end in a right way. The children that were nigh by, being called home, no trouble followed, till one of his sons, called *Thomas*, that was farrest off, came home. Then did the Devil begin afresh;

fresh; for upon the *Lords Day* following, in the afternoon, the house was set on fire, but by his providence, and the help of some people, going home from Sermon, the fire was extinguished, and the house saved, not much loss being done. And the *Monday* after, being spent in privat Prayer and Fasting, the house was again set on fire upon the *Tuesday* about nine a Clock in the morning, yet by providence, and the help of Neighbours, it was saved, before any harm was done.

Mr. *Campbel*, being thus wearied, and vexed, both in the day, and in the night time, went to the *Minister*, desiring him, to let his son *Thomas* abide with him for a time, who condescended, but withal assured him, that he would find himself deceived, and so it came to pass: for, notwithstanding that the child was without the family, yet were they, that remained in it, fore troubled both in the day time, and in the night season, so that they were forced to wake till mid-night, and sometimes all the night over. During which time, the persons within the Family, suffered many losses, as the cutting of their Cloaths, the throwing of Peits, the pulling down of Turff, and Feal from the Roof, and Walls of the House, and the stealing of their Apparel, and the pricking of their flesh and skin with Pins. The *Presbytery* having convened at the place, for a solemn Humiliation, perswaded *Gilbert Campbel* to call back his Son *Thomas*, notwithstanding of whatsoever hazard might follow. The Boy returning home, affirmed that he heard a voice speak to him, forbidding him to enter within the house, or into any other place where his Fathers Calling was exercised. Yet he entered, but was sore abused, till he was forced to return to the *Ministers* house again.

Upon *Monday* the 12 of *February*, the rest of the Family

ly began to hear a voice speak to them, but could not well know from whence it came. Yet, from evening till midnight, too much vain discourse was kept up with the Devil, and many idle and impertinent questions proposed, without that due fear of God, that should have been upon their Spirits, under so rare and extraordinary a trial. The Minister hearing of this, went to the house upon the Tuesday, being accompanied with some Gentle-men, who after Prayer was ended, heard a voice speaking out of the ground, from under a bed, in the proper Countrey Dialect, saying, *Would ye know the Witches of Glenluce? I will tell you them;* and so related four or five persons names, that went under an evil report. The said Gilbert informed the company, *That one of them was dead long ago.* The Devil answered, and said, *It is true, she is dead long ago, yet her spirit is living with us in the world.* The Minister replied, saying, (though it was not convenient to speak to such a person), *The Lord rebuke thee Satan, and put thee to silence; we are not to receive any information from thee, whatsoever fame any persons go under. Thou art but seeking to seduce this Family: for Satans Kingdom is not divided against it self.* After which all went to Prayer again, which being ended (for during the time of Prayer no trouble was made) the Devil with many threatnings boasted and terrified the Lad Thomas, who had come back that day with the Minister, that if he did not depart out of the house, he would set all on fire. The Minister answered, and said, *The Lord will preserve the House, and the Boy too, seeing he is one of the Family, and hath Gods warrand to tarry in it.* The Devil answered, *He shall not get liberty to stay: he was once put out already, and shall not abide here, though I should pursue him to the end of the world.* The Minister replied, *The Lord*

Lord will stop thy malice against him. And then they all prayed again, which being ended, the Devil said, Give me a Spade and a Shovel, and depart from the house for seven dayes, and I shall make a grave, and ly down in it, and shall trouble you no more. The Good-man answered, Not so much as a Straw shall be given thee, through Gods assistance, even though that would do it. The Minister also added, God shall remove thee in due time. The Devil answered, I will not remove for you, I have my Commission from Christ to tarry, and vex this Family. The Minister answered, A permission thou hast indeed, but God will stop it in due time. The Devil replied, I have (Mes. Föhn) a Commission, that (perhaps) will last longer than your own. After which, the Minister and the Gentlemen arose, and went to the place where the voice seemed to come from, to try if they could find any thing. And after diligent search, nothing being found, the Gentlemen began to say, We think this voice speaks out of the children, for some of them were in their beds. The Devil answered, Thou lie, God shall judge you for your lying, and I and my Father will come and fetch you to hell, with Warlock-theeves; and so the Devil discharged the Gentlemen to speak any, saying, Let him speak that hath a Commission (meaning the Minister) for he is the Servant of God. The Gentlemen returning back with the Minister, they sat down near to the place whence the voice seemed to come from, and he opening his mouth, spake to them, after this manner. The Lord will rebuke this Spirit, in his own time, and cast it out. The Devil answering, said, It is written in the 9 of Mark, the Disciples could not cast him out. The Minister replied, What the Disciples could not do, yet the Lord having hightned the Parents faith, for his own glory did cast him out, and so shall

by thee. The Devil replied, *It is written in the 4 of Luke, And he departed, and left him for a season. The Minister said, The Lord in the dayes of his humiliation, not only got the victory over Satan, in that assault in the wilderness, but when he came again, his success was no better, for it is written, Joh. 14. Behold the Prince of this world cometh, and hath nothing in me; and being now in glory, he will fulfill his promise, and God shall bruise Satan under your feet shortly, Rom. 16. The Devil answered, It is written, Mat. 25. There were ten Virgins, five wise, and five foolish; and the Bridegroom came: The foolish Virgins had no Oyl in their Lamps, and they went unto the wise to seek Oyl; and the wise said, Go and buy for your selves: and while they went, the Bridegroom came, and entered in, and the door was shut, and the foolish Virgins were sent to hells fire. The Minister answered, The Lord knows the sincerity of his servants, and though there be sin and folly in us here, yet there is a fountain opened to the house of David for sin and for uncleanness, and when he hath washed us there, and pardoned all our sins, for his Names sake, he will cast the unclean spirit out of the land. The Devil answered and said, That place of Scripture is written in the 13 of Zechariah, In that day I will cause the Prophets, and the unclean spirit, pass out of the land; but afterwards it is written, I will smite the Shepherd, and the Sheep shall be scattered. The Minister answered and said, Well are we, that our blessed Shepherd was smitten, and thereby hath bruised thy head; and albeit in the hour of his sufferings, his Disciples forsook him, Mat. 26. yet now having ascended on high, he sits in glory, and is preserving, gathering in, and turning his hand upon his little ones, and will save his poor ones in this Family from thy malice. The Minister returning back a little, and standing upon the floor,*

the



the Devil said, *I knew not these Scriptures, till my Father taught me them. I am an evil Spirit, and Satan is my Father, and I am come to vex this house;* and presently there appeared a naked hand, and an arm, from the elbow down, beating upon the floor, till the house did shake again, and also the Devil uttered a most fearful and loud cry, saying, *Come up Father, come up: I will send my father among you. See, there he is behind your backs.* The Minister said, *I saw indeed an hand, and an arm, when the stroak was given, and heard.* The Devil said to him, *Saw you that? It was not my hand, it was my fathers; my hand is more black in the loof. Would you see me? Put out the candle then, and I shall come butt the house among you like fire-balls.* After which all went to Prayer, during which time, it did no harm, neither at any other time when God was worshipped. When Prayer was ended, the Devil answered and said, *Mes John, if the Good-mans sons prayers at the Colledge of Glasgow, did not prevail more with God, than yours, my father and I had wrought a mischief here ere now.* To which one of the Gentlemen replied, though a check had been given him before, *Well well, I see you confess there is a God, and that prayer prevails with him, and therefore we must pray to God, and will commit the event to him.* To which the Devil replied, *Yea Sir, you speak of prayer, with your broad lipped Hat* (for the Gentleman had lately gotten a new Hat in the fashion with broad lips) *I'll bring a pair of Shears from my father, that shall clip the lips of it a little.*

The night now being far spent, it was thought fit every one should withdraw to his own home. Then did the Devil cry out fearfully, *Let not the Minister go home, I shall burn the house if he go; and many other wayes did he threaten*



threaten. And after the *Minister* was gone forth, the *Good-man* being instant with him to tarry, whereupon he returned, all the rest of the company going home. Then said the *Devil* to the *Minister*, *You have done my bidding.* *Northine*, answered he, *but in obedience to God, have I returned to bear this man company, whom thou dost afflict.* Then did the *Minister* call upon the Name of God, and when Prayer was ended, he discharged Mr. *Campbel*, and all the persons of the Family, from opening their mouth, in one word to the *evil spirit*, and when it spake, that they should only kneel down, and speak to God. The *Devil* then roared mightily, and cryed out, *What? Will ye not speak to me? I shall burn the house, I shall strike the bairns, and do all manner of mischief.* But after that time, no answer was made to it, and so for a long time no speech was heard. After this, the said *Gilbert* suffered much loss, and had many sad nights, not two nights in one week free; and thus it continued till *April*. From *April* to *July*, he had some respite, and ease. But after, he was molested with new assaults: and even their *Victuals* were so abused, that the Family was in hazard of starving; and that which they did eat, gave them not the ordinary satisfaction they were wont to find.

In this sore and sad affliction, Mr. *Campbel* resolved to make his address to the *Synod* of *Presbyters*, for advice and counsel what to do, which was appointed to convene in *October* 1655, namely whether to forsake the house and place, or not? The *Synod* by their Committee, appointed to meet at *Glenluce* in *Feb.* 1656, thought fit, that a solemn Humiliation should be kept thorow all the bounds of the *Synod*, and amongst other causes, to request God in behalf of that poor afflicted Family, which being carefully done

done, the event was, through the Prayers of his People, that his trouble grew less till *April*, and from *April* to *August*, he was altogether free. About which time, the *Devil* began with new assaults, and taking the ready meat that was in the house, did sometimes hide it in holes by the door-posts, and at other times did hide it under the beds, and sometimes among the Bed-cloaths, and under the Linings; and at last, did carry it quite away, till nothing was left there, save Bread and Water to live by. After this, he exercised his malice and cruelty against all the persons of the Family, in wearying them in the night time, with stirring and moving thorow the house, so that they had no rest for noise, which continued all the moneth of *August* after this manner. After which time, the *Devil* grew yet worse, and began with terrible roarings, and terrifying voices, so that no person could sleep in the house, in the night time, and sometimes did vex them with casting of stones, striking them with staves on their beds in the night time: and upon the 18 of *September*, about midnight, he cried out with a loud voice, *I shall burn the house*; and about three or four nights after, he set one of the beds on fire; which was soon extinguished, without any prejudice, except the bed it self: and so he continued to vex them.

## OBSERVATION XXI.

I Need not make any apology for inserting this Observation, even though it be well known upon the matter in this place. But because the thing is extraordinary, and that there are many who have not so much as heard of it, I have therefore presumed to mention it here. The matter is shortly this. There's a certain Woman, named *Mistress Low*, who had a real and true Horn, growing upon the right side of her Head, three inches above her right Ear. The length of it is eleven inches, and two inches about. The form is crooked spirally. It is convex on the outer side, and somewhat guttered in the inner side. It is hard and solid, and all very near of the same greatness. It is not hollow within, as horns are ordinarily, but full, yet it seems to be spongy as a Cane is. It was seven years in growing, and was cut off in *May 1671*, by *Mr. Temple*, an expert Chirurgeon here at *Edinburgh*.

## OBSERVATION XXII.

THIS Observation is for finding the *Primum vivens* in Animals. Albeit I doubt not but the red Spirit, or Blood, in most Terrestrial Animals, is the first product of the Primigenial juice, and therefore not improperly named the true *Callidum Innatum* of these Creatures, by the Noble and Ingenious *Harvey*, in his Book *de Generatione*. Neither do I scruple to yeeld, that the Heart, and appendent Vessels, are the first formed, and perfected parts in the hotter kind of Animals: yet I am confident to affirm, that in many of the colder, and moister kinds of Aquaticks, if not in all, neither the redness and heat of the  
Vital

*Vital Spirits*, nor the formation of the *Heart*, *Liver*, &c. are previously requisite, to the structure and existence of the other parts; seeing the light of life, which at first inhabited the clear and Cristalin radical moisture, before the formation of any particular part, doth alwayes move in every living creature, according to their particular exigency, without any absolute dependency upon any one part, or member (excepting singular conditions, wherein they may be stated) as to its substance, light, and motion: there being in some *Animals* a simple undulation, in others a slow creeping, but in the more perfect, an impetuous running, or rather flying of the *Vital Spirits*, necessarily required for illumination and vivification of the whole.

For confirmation, I shall give you this singular Experiment. About the middle of *March*, the sperm of *Frogs* (according to the number of *Prolifick Eggs* therein contained) sends forth a multitude of small round Creatures, covered with a black, and moveable *Frock*, which about the end of *March*, and beginning of *April*, by the Gyration of a Tail behind, like a Rudder, do slowly move their bodies in the Water. At this time having opened severals of them, I found nothing (apparent to the naked eye) but a clear thin Membran, under the fore-named black *Frock*, within which were contained a clear Water, and some small Fibres like Intestines, and in the fore-part a small orifice like a mouth. About the middle of *April*, its motion is more vigorous, and the *Tripes* within are most evident, lying in a very fine circular order, but as yet, there is no Vestige of *Heart*, *Blood*, or *Liver*, &c. About the middle of *May*, the feet formed like small threeds, appear thorow the black *Coat*: within the Breast, the Heart is then visible, of a white and Fibrous substance, the Liver

is white, and the Gall therein easily discerned. But (which is the head of this Experiment) the Vital Spirit, in form of a clear and pure Water, is manifestly received by the Nervous Heart, and by the contraction thereof transmitted to all the Body, thorow white transparent Vessels, which being full of this Liquor, do represent the *Lymphatick*, rather than the *Sanguiferous Veins*. Last of all do the *Pneumatick Vesicles* (which in this *Amphibium* supply the place of the Lungs) arise in the Breast, after whose production, the Lymphid and Crystallin Liquor, while the Heart is turgid therewith, seems to be red and fiery, but in the other Vessels, it is of a faint pale colour, untill (about, or near the end of *June*) the *Frock* being cast off, and a perfect *Frog* formed, the whole Vessels are full of Blood, or a red substance very thin, and clear: the Liver, and *Pneumatick Vesicles*, &c. become red, and Rosy; so that the Blood in this *Amphibium* (which in the more perfect Animals is first compleat) seems to be the last part in attaining its perfection.

That *Salmonds*, and great *Trouts* have an aqueous liquor which runs thorow their *Arteries*, and *Veins*, before their Blood attain the true consistency, and saturat tincture I am certain: whether it hold in many others, I suspect, but dar not affirm. Hence it may be (if mens observations, were frequent in all kind of *Anatomical inspections*, in several *Embryo's* of every *species*) it would be found evident, that the Blood in all these, called *ἰσχυρὰ*, hath its immediat original from a simple homogeneous, and uniform liquor, and doth by gradual and frequent influences of the vital ferment of the heart, receive at length the full tincture, essence, and subsistence requisite for vivification, and illumination of the whole members.

Whether

Whether this Experiment doth not sufficiently impugn the universality of the hearts first living, the original of the Gall from the fervour, and ebullition of the Blood, the production of the Blood by the Liver, and many other ancient errors, let any judge, who will but take pains to make and compare *Harveys* trials *de ovo*, with this of the *Per-wigl* or *Gyrinus*, *ab ovo*.

Yea, if the aqueous liquor, be not one with the vital Spirit, and subsequent Blood, then my eyes, and taste are altogether erroneous.

Moreover, it were to be wished, that *Physicians* would not simply stand upon the *Galenick* suppositions of the four alledged Components of the Blood, nor any such, or equivalent fancies of the latter *Chymists*; but that they would seriously examine the first original, and rise thereof from the *Primigenial* juice, or *liquamen*, the progress, and perfection of its tinctures, how many renovations, or new tinctures it is capable of; the vast difference between the Blood of old and young *Animals*, (though, it may be, they are both *univocal* substances, while in their integrity within the Vessels) with the *specifick* discriminations, not only of that of any one *Aquatick*, from any *Volatil*, or *Terrestrial*, but likewise of any one *Species* living in the same Element, with these that enjoy the same Aliments, but of a different *Species*. And lastly, the variety of particular constitutions, and singular properties of individual *Animals*, radicared in the fountain of life, or first original of the Blood. If these things, and many more, were truly inquired after (though the Cook be sometimes necessitated to throw away some of the Broth with the Scum) I doubt not but the *Neoterick* Invention of *Transfusion* of Blood, would prove altogether ridiculous, and the ancient mistake of too



much *Profusion* of this treasure by *Pblebotomy*, might suffer some reasonable checks from infallible Experience; and sound reasons, not here to be mentioned. There are truths in Natural Philosophy, which (I doubt not) but sound reason and experience will convince the vain world of in due time.

## OBSERVATION XXIII.

**T**His Observation is concerning the aliment and growth of Plants. The inquisitive wits of this, and the last age, having rejected the old opinion of the earths nourishing of Plants, or being converted into their aliment, have made many laudable Experiments for finding out the materials, and means of their growth, and vegetation, such as Sir *Francis Bacon's Observe of Germination*, *Helmonts of a Willow*, and the Noble *Mr. Boyle's of a Gourd*, &c. For though a Tree be cut down, and the root thereof wax old in the earth, and the stock die in the ground, yet through the sent of Water, it will bud, as *Job* speaketh, *Chap. 14. 7, 8, 9.* I shall add a short remark of a Willow growing without earth. Upon the 13 of *April 1662*, I set a top branch of the *Peach-leaf'd Willow* in a Glasse-viol, among 12 ounces of pure Spring Water, with three small buds upon the top thereof, scarce yet discernable. The first ten or twelve dayes, little white specks appeared upon the sides of the Willow, like small drops of *Quick-silver*, or like the first Bubbles that arise upon the fermentation of Ale or Wine, but no consumption of the Water all this time. Indeed the *Gemms*, which stood three inches above the Water, did visibly swell about the twelfth day. About the fifteenth day, I perceived small white roots within the Water,

Water, upon several places of the *Plant*, and observed the Liquor grow somewhat thick, and decay in bulk considerably. Having perceived this, I took another Glass of the same bigness, with that wherein the *Willow* grew, and having filled both top-full with Spring Water, I observed clearly the consumption of the Water wherein the *Plant* stood, to be so great, that during *May*, *June*, and a great part of *July*, every week (at least) an ounce and an half, or two ounces of it were insensibly spent: whereas the other Water, standing by in an open Vessel of the same size, made not waste of one spoonful in a whole moneth. About the middle of *August*, the Water turned very thick, and green, like that whereon *Duck-weed* useth to grow, and the fair white roots were all obscured from the sight, although the Vessel by the multitude of roots was not capable of the third part of Water it received at first. At this time the branches were advanced to half the bigness, and a much greater length, than the whole stock, at its first planting; and the leaves of as fresh a verdure, as any *Willow* in the fields. Thus, having observed, that a tree of four ounces weight, could in three moneths time, and little more, consume insensibly, seven or eight times its own weight of pure Water, without the warm preservation of the earth, and by its own proper digestion, to thicken the remnant of the Water, that it might serve for *lorication* of the tender fibres of the roots, I took the Glass, the Tree, and all, and threw them over a Window, supposing it needless to recruit the Water any more, and judging it impossible without the warm guard of the earth, that the naked Tree could be preserved in Winter: yet it had the good fortune to fall among some thick Herbs in the corner of a little Garden, where (after it had lien all Winter) it was

was found, and brought back to me, the branches fairly budding in *April*, the whole Tree fresh and green, yet very little Water was left in the Glass, by reason, as I judged, it had fallen upon its side. Then I endeavoured to keep Water about it, but the Stock filling the neck of the Viol, and the Roots the whole body thereof, the starved *Plant* died in *May*, after it had lived a whole year without earth. From this it would seem, that this kind of Tree, (and it may be, many more) doth dissipate insensibly six times more Liquor, than it doth assimilate, and by consequence, that a great quantity of moisture is necessary for maintainance of great Woods. Neither is there any way so advantageous for draining moist ground, where there are no living Springs, as that of planting abundance of Timber, which will best agree with that kind of soil: for by this means, what was formerly noisome, and superfluous, is now converted partly into the useful aliment of the Timber, and partly sent abroad in insensible exhalations, which (according to the nature of the emitting *Plants*) prove either very noisome, or wholesome to the Neighbour-Inhabitants. Great care therefore would be had in the choice of such Trees, as are to be planted in such moist ground, as are near to mens dwellings, or places of concourse. They are not fools, who prefer *Firs*, and *Lime-trees* in their *Avenues* to *Oak* and *Elme*. Let the effects of the *Atomical* exhalations of *Alder* and *Oak* upon fine Linnen, and white Skins be more particularly noticed.

Having spoken somewhat of the aliment and growth of *Plants*, I shall in the next place give a short hint at the motion of their aliment, especially of Trees. That the alimentary juice of *Plants*, is much thinner, than that of *Animals*, no man, I suppose, will deny, seeing that is conveyed

veyed thorow the trunk, or body of the *Plants*, by inperceptible pores; but *this* (for the most part) is sent thorow all the members, through patent and manifest Vessels. But how the nourishing, and vital juice in *Plants* doth move, and by what passages, hath not yet been made known, by any that I have seen. I made once a few Observations, for trying of the motion of the aliment of Trees, which bred in me this conjecture. The nutritive juice of Trees is transmitted both to the roots and branches, through the heart, or pitch, and woody pores of the Timber, and when it is come to the extream parts, it returns again from the tops of the roots and branches, between the bark and timber, into these forenamed interior passages, and so back to the extremities again, and that continually, so long as the life remains. And because the substance of that skin, or bark, which invests the fibres of the root, is more open and porous, than that which is upon the outward branches: therefore it seems, that so much as is superadded to the stock of the former aliment, from the earth, is conveyed to the heart and pitch, by means of, and together with, that part of the retrograd juice, which returns from nourishing, and enlivening the timber of the root-branches, (for it is an easie Experiment, to make the top of any Tree become root, by laying it down) and receives the impressions of the life of the Tree, common to the whole mass of alimentary juice, like the *Chyll* in *Animals* mixed with the blood of the *Veni-cave*, before it come to the heart.

This motion is not to be thought alwayes alike swift, or of equal celerity: for the vital juice of the Tree becomes so thick and oleagenous in the Winter, that the motion thereof to the outward, is scarce discernable (though the preparation of the *Gemmes*, both for leaves and flowers,

are

are observed by the curious, and can be distinguished, even in the coldest seasons) and the returns inward are in so small quantities, that they are rather like vapours, than liquid juice. Indeed, some Trees, when their root-branches are cut (even in Winter) will yeeld no small quantity of an acid liquor, which by addition of the recent *Lef-fas* from the earth, smells evidently of the Matrix, from which it did proceed. Moreover, the passages especially from the branches to the Trunk, are so straitned and contracted, that the bark cleaveth to the Timber, as every Wood-man knows. But so soon as the warm Spring hath attenuated the ever-flowing juice in the whole Tree, then doth it become turgid, and more aqueous over all: the passages, and channels both in the trunk, and among the tunics, and particular skinnies, are so palpably filled with this vital juice, that having no sufficient place to be comprehended in, it putteth forth new growths both in the top, and in the root, which may be easily seen to have more pitch than wood, and to be sealed on the extremity, with the vestiges of a future Gemm; that by the former, they may the more freely receive the vital influences from within, and by the latter, may be secured from the depredation of the external Air.

To prove the motion *ad extra*, or to the extremities of the branches; take the branch of any ordinary Tree, about the bigness of a mans wrist, make it bare near the body of the Tree of all bark, and subjacent tunics (for every Tree according to its kind, hath more or fewer skins, which serve for Veins, within the strong outmost Cortex) at least for the breadth of a span, or two hand-breadth. Then tye up the place, so excorticated with a *compoff*, made of horse-dung mixed with earth; let it stand so from May, till

till *November*. Then cut off the branch, a little above the *Compost*, near the body of the Tree, and you shall find it living and fresh, like the rest of the branches: yea, small roots shall evidently appear to have come forth under the *Compost* near the bark, but not under the bared place. This branch in many kind of Trees being planted, will hold, though not in all. I say then, seeing the foresaid bough is nourished from *May* till *November*, it is necessary, that it receive nutriment from the body of the Tree, by the internal porosities thereof: for the bark being discontinued by *excortication*, can send nothing upward towards the top of the bough; and if it received nothing from the root, it would wither in a few dayes. Yea, leave the discovered part naked, but for a few dayes, and of necessity the branch dieth, the aliment thereof being exhausted by the Air, before it can reach the extremities of the bough.

That the *Vital Balfome* of the Tree returns from the extremities by the internal bark, and inward superifice of the external, together with the smooth outward part of the trunk, although the necessity of both timber and bark in all *Incisions*, and *Inoculations*, might perswade the judicious, and the visible course of the juice of the *Sycamor* in *February*, and of the *Birch* in *March*, upon the cutting of any small branch, might convince any curious beholder; yet the *knot* or *callus*, that is made upon grafted Trees, will better inform the ignorant: for this *knot* being alwayes upon the shoulder, or root of the Graff, and never upon the top of the Stock, doth evince clearly, that it is made by *refagnation*, of the descending, and not of the ascending juice: otherwise, why doth it not swell the top of the Stock, as well as the root of the Graff? Or why doth it not extuberat in any other place of the Graff? These



are accidental *varices*, which can hardly be shunned in Imping, seeing the top of the Stock (except when it is very young and succulent) doth not receive so kindly, as it ought, the retrograd sap, although all that is sent out to the Grass must ascend thorow the pores of the Stock. Hence many times a considerable part of the Stock is mortified, because although abundance of aliment ascends to the head or top thereof, yet no more of it goes to the branches, but what is bestowed upon the Grass, a great part of the rest being exhaled by the Air (especially in big Stocks) and consequently, the place defrauded of its nourishment: no other wayes than when the motion of the vital sap faileth, either in the whole, or in part, a total decay or particular mortification of some part necessarily follows, as in the Stems of annuall Plants, and mortified tops of the *Ectrapelous* branches (that I may so call them) of *Willows*, *Plumbs*, &c. we may observe every *Autumn*.

## OBSERVATION XXIV.

Sir,

I Was not a little surpris'd, at the receipt of yours, when I had considered your desire in it, being prest with two difficulties, which seem'd equally hard to evite. The one, to give you my judgement in a matter wherein I have been so little conversant my self, and have had the steps of no other to follow, never one having hitherto touch'd that subject in writting; I mean of *Coals*, and other *Minerals* of that nature, their *Course*, and other things relating thereunto; the observation whereof (I grant) wants not its own pleasure, and usefulness. The other, to refuse the desire of a friend, when importuned,

to

" to whom I owe my self, by many obligations. This last  
 " having prevailed, hath determined me to assay the over-  
 " coming of the first. And though I am confident, what  
 " account I can give you, shall give but very little satis-  
 " faction: yet I adventure to offer it, such as it is, very  
 " freely in the following discourse, wherein you are not to  
 " expect, that I will meddle with some questions, there-  
 " anent, which might be more curious, and pleasant, then  
 " profitable, or satisfying, such as, if *Coal*, and *Free-stone*,  
 " which keep one *course*, and have the same accidental  
 " qualities, have been created in the beginning, in their  
 " perfection, as wee now find them, and since that time  
 " only preserved, as they were created for the use of men,  
 " to whom all sublunary things were made subservient?  
 " Or, if they have been but produced gradually, as they  
 " speak of *Gold*, and other *Minerals*, by the influence of  
 " the *Sun*, in the bowels of the Earth? And if their pro-  
 " duction be of that nature, out of what matter they are  
 " formed? These things being above my reach, I shall leave  
 " their inquiry, to those that are knowing in the secrets of  
 " Nature, and shall therefore give you a narration, of  
 " what either I have observed of these things, which oc-  
 " cur in the *Winning* of *Coal* in my own experience, or by  
 " conversing with others of more experience than my self,  
 " in doing whereof, I shall follow this Method.

First, I shall speak of these things that are common to all  
*Coal*, wherein they all agree, and which are, as it were, *essen-*  
*tial* to all, and of there differences, which are but acciden-  
 tal, and gradual sometimes, and yet are abundantly conspi-  
 cuous, and causeth different effects in the *working*, as their  
*Dipps* and *Rise*, and *Streek*, for so are they termed.

Secondly, of some things, which are but accidental to *Coal*,

and yet so ordinary, that scarcely any is found without them, in lesser or greater degrees; such are *Gae's*, and *Dykes*, that alter the natural *Course* of the *Metalls*, very incident to every *Coal*, though in some less frequent, conform to the nature and kind of the ground, where the *Coal* is.

Thirdly, I shall speak something of *Damps*, and of their different causes, and effects: of *Wild-fire*, and other such like things, which are met with in the working of *Coal*.

And lastly, of the best way for trying grounds to find *Coal*, where never any hath been hitherto discovered: of carrying on of *Levels*, for draining the water of *Coal* and making it workable.

It is to be considered, that all *Free-stone*, though of different natures, hath the same *course*, with the *Coal*, that ly either above them, or below them, except it be accidentally, interrupted: therefore, whatsoever is spoken of the one, is applicable to the other. And so we find in *Digging* or *Sinking*, that after the *Clay* is past, which keeps no *course*, all *Metalls*, as *Stone*, and *Tilles* (which are *Seems* of black *Stone*, and participat much of the nature of *Coal*) ly one above another, and keep a regular *Course*; wherein the three things most remarkable are their *Dipp*, and *Rise*, and their *Streck*, as it is termed.

The *Dipp*, and *Rise*, are nothing but a declining of the whole body of the *Metalls*. And this general holds, that all of them from their *Center* rises, till they be at the very surface of the *Earth*; some only at a foot or two foot, some at an ells distance from the surface, which is here termed a *Cropping*: and whether *Coal* or *Stone*, the nearer they come to the surface, the softer they become, till at  
last

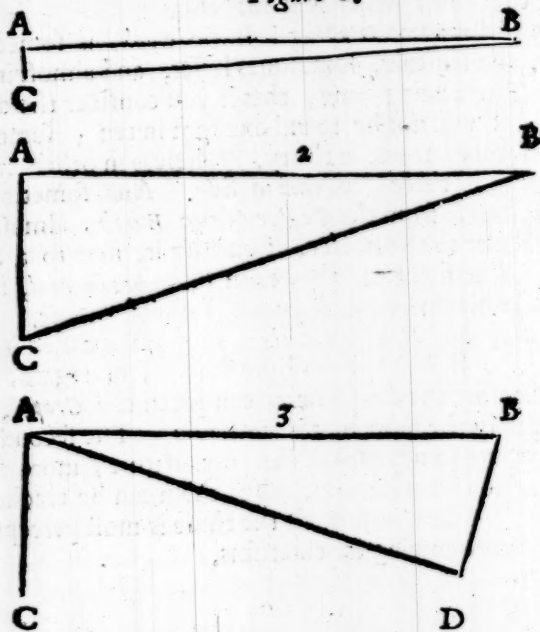
last they are converted, if it be a *Stone*, to a very *Sand*, and if *Coal*, to a *Dross*, which will not burn.

This declining or *Dipping*, of the *Coal*, is sometimes greater, and sensible, sometimes lesser, and almost insensible. There being some, that if you consider the declination, it will not be found one foot in ten; some one foot in twenty, or one in thirty. Whereas in others it will be one foot in three, or one in five. And sometimes it hath its *Course* from the *Center* of the *Earth*, almost in a perpendicular to the surface, it cutting it, near to a *right Angle*. The first sort, they term *Plate-broad-coal*, in regard of the plainness, and evenness of its *Course*. The next, they call *Hinging-coal*. The last is called *Edge-Coal*. The first is the most profitable, in regard, that it's long before the *Coal-hewers* can reach the *Cropp*, and consequently the more of it is workable. The second and third sort, are sometimes of their own nature, more firm, and fitter for burning, but less of them can be reached in working. The *Course* of all the three is most perceptible in the three following Schematisms.

---

Figure

Figure 1.



In all the three Figures, the point B is the *Cropp* of the *Coal*. The Line BC is the body of the *Coal* declining or the *Dipp* from the *Cropp*. AC is the perpendicular, falling from the Horizontal Line, whereby the true declination or *Dipp* of the *Coal* is found. So that after you have found your *Coal* at B, you must set down your *Sink* at the point A. In the *Flat-broad-Coal*, which we suppose only to decline, three fathoms in sixty; the *Sink*, that answers to the perpendicular AC, will be of deepness three fathoms,

thoms. If the distance B A, be supposed to be 120 fathoms alongst the *Grass*, or surface, then will the deepness of the *Sink* be six fathom, and so forth. In the second, if the *Coal* be supposed to decline one fathom in three, the *Sink* A C, being set down at the same distance from the *Cropp* B, with the former, it will prove thirty fathom deep. If the said distance be doubled, it becomes sixty fathom deep, and so forth. In the third, keeping that same distance alongst the surface, you shall not encounter the *Coal* with a Perpendicular *Sink*, because of its great declination, and therefore through want of *Air*, and other difficulties, you cannot dig so deep, as is necessary to that effect, except the *Sink* should be made to decline, as doth the *Line* A D. All these *Dipps* are to be seen in several places of *Lothian*. The first is most conspicuous in the Earl of *Wintons* ground at *Tranent*, where the *Coal*, and other *Metals* are extraordinary flat and even. The second is within the said Lordship of *Tranent*, in a piece of ground, called *Wester-Fan-side*. The third in *Lonhead* of *Laswaid*, which pertains to Sir *Fohn Nicolson* of *Nicolson*: and in many other places, one may see very different declinations, who is curious to observe them.

From this general position of the *Dipp*, and *Cropp* of all free *Metals*, there is one consequent, which is no uncouth Observation, namely that these *Metals* rising from their *Dipp* to a *Cropp*, every one of them riseth in their proper course, if none of these things whereof we shall treat hereafter intervene, and make an alteration, that is the *Coal* or *Stone*, which is lowest, comes farrest out in its *Cropping*, which is easily understood by the sublequent Schematism.

Wherein

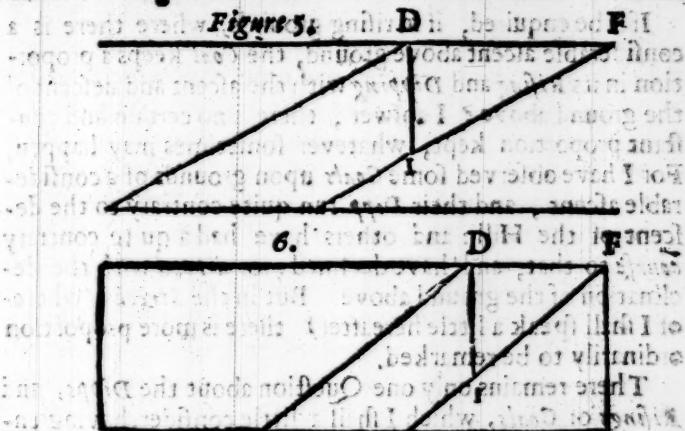


Figure 4.



Wherein the Line AM represents the surface of the *Earth*. CD. EF. GH. IK. LM, are so many several *Metals*, lying in *course* one above another. Suppose CD were a *Stone*, and the *Roof* of the *Coal* EF (for so they term the *Stone*, immediately next above the *Coal*) and GH, IK, were other two *Stones*, intervening between the *Coals* EF, and LM, then if the *Cropp* of the uppermost *Coal* be found at F, the *Crop* of the *Stone* above it, must be found back, at the point D, and the *Cropp* of the *Coal* under it, which is LM, must be found at M. And this distance of *Cropp* is proportioned by the length of the perpendicular between them, and the quantity of their declination. For, the more even and flat a *Coal* is in its *course*, and other *Metals*, above and below, the farther doth the *Cropp* of the lowest *Coal* advance before the *Cropp* of the uppermost. For illustration whereof, let us suppose in two several grounds, two *Coals*, between which, there is an equal distance of perpendicular. And suppose the *Metals* in the one ground to decline at 13 to 24, the other at 13 to 16, then will the distance between the *Cropp*s in the two grounds be very considerable, as may be represented by the two following Figures.

Figure



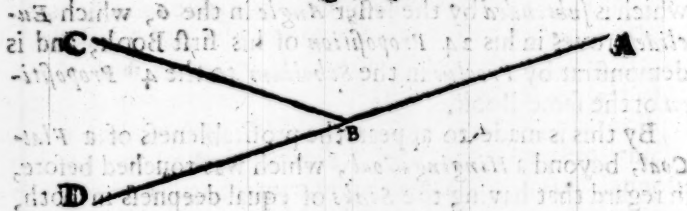
Suppose then, that  $DI$ , is of equal length in both *Triangles*, which is the perpendicular, between the two *Goals*: yet  $DF$  in the fifth Figure, is much longer than  $DF$  in the 6. And the reason is evident, because the *Angle*  $DIF$ , in the 5, is greater then the *Angle*  $DIF$  in the 6: and therefore the *Base*  $DF$ , which is subtended by the greater *Angle* in the 5, must be greater then the *Base*  $DF$ , which is subtended by the lesser *Angle* in the 6, which *Euclide* proves in his 24 *Proposition* of his first *Book*, and is demonstrat by *Proclus* in the *Scholium* to the 4<sup>th</sup> *Proposition* of the same *Book*.

By this is made to appear the profitableness of a *Flat-Coal*, beyond a *Hinging-Coal*, which was touch'd before, in regard that having the *Sinks* of equal deepness in both, there is much more of the *Flater-Coal* to be wrought, before it *Crope* out, then of the *Hinging*, as there is a difference between the *Lines*  $DF$  in the first and second *Figure*, or between the *Lines*  $FF$ , in the same.

If it be enquired, if in rising grounds, where there is a considerable ascent above ground, the *Coal* keeps a proportion in its *Rising* and *Dipping* with the ascent and descent of the ground above? I answer, there is no certain and constant proportion kept, whatever sometimes may happen. For I have observed some *Coals* upon grounds of a considerable ascent, and their *Dipp* run quite contrary to the descent of the Hill: and others have had a quite contrary course to that, and have declined, or *dipped* with the declination of the ground above. But in the *Streek* (whereof I shall speak a little hereafter,) there is more proportion ordinarily to be remarked.

There remains only one Question about the *Dipps*, and *Risings* of *Coals*, which I shall a little consider, having encountered different judgements anent it, in conversing with persons, who had experience in *Coal*, viz. whether *Coal* and other Metals, after they have declined such a length from their *Cropp*, suppose from *West* to *East*, take another course, and rise to the same point, to which formerly they dipped?

Figure 7.



As if the *Coal* dipped from A, which is the *Cropp*, to B, which should be the *Center* of that Body; and after that rise to C? Or if it should continue its declination thorow

B to D, which is *Antipodes* to us? I shall not offer to determine in a matter wherein there can be so little certainty attained, but shall give my opinion, which is founded upon the experience I have had, and Observations I have had occasion to make on that Head. And first, I find in all these *Coals*, wherein no contrary *Cropp* or *Rising* could be visible, there are invincible obstructions, as either, they have been near the *Sea*, and have *dipped* that way, and so if they took any contrary *course*, the *cropping* behoved to be in the *deeps*, and so no access to trace them. Or next, they have *dipped* towards the foot of a Mountain, and so the ground above rising the same way which they declined, their *course* could not be pursued, till a contrary rising should be discerned. Or thirdly, they have encountered some *Gae*, or *Dyke*, which hath cut them off, before they came to their full *dipp*, and thus their *course* was obstructed. Now, those that have been acquainted with no other *Coals* but such, I think it not strange, if it be hard to persuade them of those things they have not seen. But besides all those kinds, I have seen others, whose contrary *rising* and *dipping* have either been visible to the eye, or demonstrable by reason. For example, I have entered under ground, as it were at the point C, at the very *Grass-cropp*, and have gone following the *dipp* of that *Coal* to the point B, at which the *course* hath altered, and carried me out at the *Grass* at A, which are two contrary points of the Compass. And that alteration of *course* was not occasioned by any *Gae*, or *trouble*, which sometimes have that effect, the ground being very clean, and good *Metals*, keeping their *course* most regularly.

There are other instances for confirming my experience, in fields, which are so large, that 'tis impossible to work

the *Coal* so far to the *Dipp*, it falling deep, and so wants *Levell* for conveying water from it, or wants *Air*, for following it to such a deepness, as to overtake its *Center*, where it takes a contrary *course*, and yet the contrary *Cropp* hath been wrought in several places, which is evident to be a part of the same body, with the other, both by the nature of the *Coal* it self, by the *Minerals* lying above it, and the *Coals* below it, all which keeping the same *Course*, except when they encounter *troubles*, which are incident to some parcels of ground, more than to others. The greatest field I know wherein this is conspicuous, is in *Mid-lothian* where is to be found, the *cropping* of a *Coal* of a considerable thickness, which is termed their *great-seam*, or *Main-coal*, and the other *Coals* lying below it, which may be traced in the order following. At *Preston-Grange* these *Coals* are found *dipping* to the N. W. and rising to the S. E. which have been wrought up to *Wallisford*: from thar, along by the foot of *Fauside Hill*, the *dipping* lying in the Lands of *Innesk*, which marches therewith on the North. From thence it runs through the ground of *Carberry*, every one of these grounds from *Preston-Grange*, Giving *Levell* to another. From thence, through a part of the Lands of *Soneton*, and next through a piece of ground belonging to the Family of *Buccleugh*, called *Condon*: and through *West-houses*, which belongs to the *Earl of Lothian*, and at *Cockpens* and *Stobhill*; from thence runs through to *Carington-Mill*; all which is a *course*, which in *Streek* lyes near to S. W. and N. W. and will be in length about eight miles. From thence, the *course* of the *Coal* turns, and is found in the Barony of *Carington*, *White-hill Ramsay*, *Gilmerton*, and from thence taking its *Dipp*, quite contrary to what it had before, the other *Dipping* N and N. W.

or N E, according to the turn of the *Street*, it *Dipps* there S, S E, &c. and from *Gilmerton*, it is found at *Burntstone*, a piece of ground belonging to the *Earl of Lauderdale*: and from thence at the *Magdalen Pans*, where the turn of the *cropp* being within the *Sea*, is not seen, till it be found at *Preston-Grange*, where we began to remark its *course*. The parcel of ground, under which this great body of *Coal* lyes, is of a considerable extent, it being eight miles in length, and five or six in breadth; in regard whereof many other *Coals* are found lying above the great *Coal*, the *cropps* whereof doth not come near the *Cropp* of it, by a considerable distance.

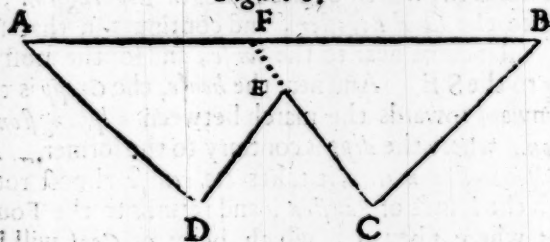
Though this instance alone, may sufficiently convince, yet I shall not be unwilling to give another. The parcel of ground, in which this *Coal* is found, is not of so great an extent, as the other, and therefore its *course* may be the more easily traced. For the greatest part, it belongs to the *Earl of Winton*, and lyes within the *Lordshp of Tranent*, whose contrary *Cropps*, are most conspicuous. This great *Coal*, which is 10, or 12 foot thick (beginning at the head of the Toun of *Tranent*) where it hath been wrought, runs S W towards the march of the Lands of *Elphinston*, belonging to the *Lord Register*, and continues in that same *course*, till it come near to the *house*, and for the most part dipping to the S E. And near the *house*, the *Cropp* is turned downward towards the march between *Elphinston* and *Ormiston*, where the *dipp* is contrary to the former. And from *Elphinston-mains*, it takes its *course* almost round, through the Lands of *Panston*, and returns to the Toun of *Tranent* where it began, which body of *Coal* will be in length two miles, and in some places, as much in breadth. Now, I leave it to the judgement of any person, if there be  
not



not more reason to perswade, that this should be the natural *course* of these *Minerals*, where such pregnable instances, to evince it, are found; then to conclude the contrary from these *Coals*, the *course* whereof cannot be followed, because of the invincible impediments, I mentioned before. However, I leave every one to be determined, by his own opinion, and shall be satisfied to enjoy my own, till these of more experience convince me of the contrary.

There are some other things harder to be remarked about the *Dipp*, and *Rise* of *Coals*, which (possibly) every one hath not seen, they being so very rare, and therefore are not fit here to be passed without being considered. One is, of a *Coal*, which having that contrary *Dipp* and *Rise*, (whereof I have been speaking) in one of the *cropps*, hath not come out to the *Grass*, and *terminat*; but after it hath *risen* a considerable way in its contrary *course*, in stead of *Cropping* out, hath taken a *Dipp* towards the same point, to which it *dipped* first, and so having *dipped* to the *Center* of its *course*, it hath *risen* again, and *cropped* to the contrary point, as is to be seen in this eight Figure.

Figure 8.

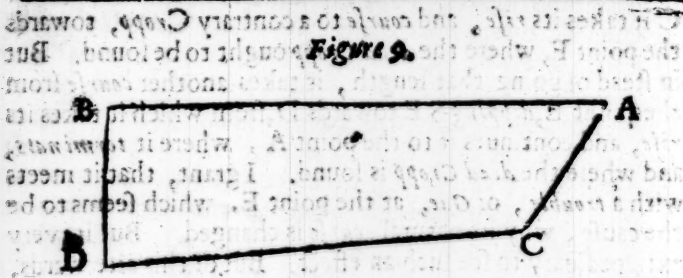


Where A B is the surface of the Earth. The point B is the *Cropp* of a *Coal* dipping from N W, to the S E. From C it

C it takes its *rise*, and *course* to a contrary *Cropp*, towards the point F, where the *dead Cropp* ought to be found. But in stead of going that length, it takes another *course* from the point E, dipping S E towards D, from which it takes its *rise*, and continues it to the point A, where it *terminats*, and where the *dead Cropp* is found. I grant, that it meets with a *trouble*, or *Gae*, at the point E, which seems to be the cause, why its natural *course* is changed. But its very extraordinary to see such an effect. But of this afterwards, in its own place.

There is yet another thing to be remarked, in the *dipps*, and *risings* of *Coals*, which is this. In the most part of *Coals*, that have their *course* from *dipp* to *cropp*, without the intervention of a *dyke* or *gae*, the declination is straight down, from the horizontal line drawn from the point of the *cropp*, to the fardest point of the *dipp*. That is, the *Coal* declining from that point in a right line, makes with the horizontal line, a *right lined angle*, *angulus rectilineus*, though in some the *angle* is more *acute*, and in others less, as is to be seen in the first, and second figures, where A B being the horizontal Line, and B the *cropp*, B C is the body of the *Coal* declining, which meeting with A B in the point B, constitutes a *right lined angle*, and where ABC in the second figure, is a greater *angle*, then A B C in the first. Yet I have seen a *Coal*, the body whereof from the *dipp*, or fardest point of declination, had its *rise* towards the *cropp* very insensibly, it being *Flatt*, and then began to be more sensible, till at last coming near to the surface of the Earth, it takes in a sudden such a *rise*, that from declining one foot of 12 or 14, it declines now one foot of three, as may be made evident from this following Figure.

Figure



Where A B is the Line drawn from the extream points of the *Cropp*, right horizontal. The body of the *Coal* rising insensibly, is D C. But as soon as it comes to C, it riseth with a great ascent till it *Cropp* out at A. Here you see, that in stead of one side of a *Triangle*, which the *course* of other *Coals* in their rising, or in their declination makes, this *Coal* in rising makes two sides, namely D C, and C A, the Figure D B C A being quadrilateral. The *Coal* of this *course* was really wrought, and is yet visible in its waste, where there is found no *Gae* or *Dyke* to make this alteration.

These are the chief things that I have thought worthy of Observation in the *Dips*, and *Risings* of *Coals*, and therefore I come now to touch a little the other part of their *course*, which is commonly termed the *Streak* of a *Coal*. To make intelligible to those, who are not experimentally acquainted with *Coals*, this term, or what the *Streak* is, we must lay this foundation, that the *Coal* is a *Physical Body*, and so hath its three principal dimensions, which do constitute it so, viz. *Longitude*, *Latitude*, and *Profundity*. Its *Latitude* is that part contained between its extream lines, which is measurable by its surface, to which

its *dipping* and *rising*, though alwayes incident, yet is but accidental. Its *Profundity* is to be measured by the distance, between the two surfaces, immediately next to it, above and below: which are termed in *Coallery* its *Roof* and *Pavement*, because of the resemblance they have to the *Roof*, and *Pavement* of a house. The *Longitude* is nothing else but what is termed by the *Coal-hewers*, the *Streek*. For if you imagine a Line drawn along the extrem points of the *Rise*, or *Cropp* of the *Coal*, that is properly the *Streek* of the *Coal*.

There are but few things to be remarked, as to this part of *Coal*: only first to find how it lyes, to what points of the Compass it moves. For knowing whereof, there is this general Rule, that, having found your *Dipp* and *Rise*, to what ever Points that *Course* is directed, the *Streek* is to the quite contrary. For supposing a *Coal Dipp* S E, the two points, that respect the *Dipp* and *Rise*, must be S E, and N W, being the points opposite one to another. Then it must needs follow, that the *Streek* must run S W, and N E, which two *courses* divides the Compass, at *right Angles*. And therefore, where a *Coal* is found to have contrary *Dipps*, and *Risings*, they declining sometimes to all the Points of the Compass (whereof there hath been given two notable instances before) it must needs follow, that there be also contrary *Streeks*, and so the *Streek* of a Body of *Coal* is sometimes found to describe a round figure, though not perfectly circular, and sometimes a *multangular* figure. For it cannot be supposed that the *Streek* makes alwayes a right Line, between the two points, from which it is reckoned. For example, between the *Laire* of *Preston-grange* his house at *Preston-pans*, and the *Stob-hill*, there are the *Streeks* of several *Coals*, lying one a-

have another, which will be at length, about seven or eight miles, lying near upon S.W. and N.E. ; yet the *Cropps* of the said *Coals* (their *dipp*, and *rise*, being N.W. and S.E.) are sometimes farther advanced towards the S.E., sometimes farther back towards the N.W., by the difference of a mile, and this generally occasioned by the encounter of a *Dyke* or *Gae*, whereof hereafter.

The same question, that occurred in the *Coals* dipping towards a Hill, or rising above ground, comes to be inquired into here ; viz. If a Coal encountering an ascent, or *Brae* above ground, in its *Streck*, rises also with the ground, and keeps its ascent : I answer, I have found it so in all the *Coals* I have ever seen of that nature. GOD in his providence, having so ordered it, that thereby it may be the more useful, in regard more thereof may be wrought by one *Tunnel* or *Aqueduct*, by which the Water is convey'd away, as afterwards will be observed in speaking to *Tierwells*. For confirmation whereof, I shall bring instances both of *Coals*, that declines towards the Hill, and of others that declines with the same *dipp*, the Hill hath it self. In the *Coals* of *Bonhard*, *Grange*, *Kinglassy*, and *Kinneil*, which keep all one general course, the ascent above ground is from the Sea, (which lyes North), towards the South, or thereabout : the *Coal* dips, or declines towards the N.W., and so consequently rises to the S.E. The *Streck* of these *Coals*, is from the N. Ext. S.W., which stops alongs the Hill, and comes up to the top thereof to the Westward of the House of *Bonhard*. Now, in sinking in that ground, if an equal proportion be kept, in all the *Sinks* from the *Cropps*, and a just allowance given for the different rising above ground, the *Sinks* will be near of an equal deepness along all the *Streck*. So that a *Sink* upon the same

same Coal near to the Sea, which is the N E point of the *Streck*, at equal distance from the *Cropp*, will be as deep as a *Sink* upon the top of the Hill, being the S W point of the *Streck* at the same distance from the *Cropp*, allowing alwayes the different *rise* above ground, and excepting some particular *troubles* falling in upon the Metals of one *Sink*, and not of another, and so making them *dipp* more, which will occasion a difference of the deepness. The same is also found in the Coals of *Dysart*, and *Weems*. As also in that great body of Coal before mentioned, between *Preston-grange* and *Stobhill*, the declination whereof is to the N E, which is also the *course* of the descent above ground.

Another instance is from the Coals within the Lordship of *Tranent*, the *dipp* whereof is of another *course*, being contrary to the descent of the Hill, viz. the Coal *dipping* to the S E, and consequently the *Streck* running S W, and N E, where the same is to be observed that was seen in the other, anent the equality of the deepness of *Sinks* along the *Streck*, with the same allowances, and exceptions before mentioned.

Some have been of opinion that *Strecks* of Coals by generally South and North, or to some of the points near to these two Cardinal ones, between South and S W, and North and N E, as South and by West, and North and by East, &c. To which general I cannot agree, in regard of what I have before made evidently appear, viz. that some Coals have their *croppings* towards all the points of the Compass, and the *Strecks* being regulated by the *Croppings*, they must necessarily be judged to have their *courses* proportioned to theirs. So that if a Coal *dipp* to the true North, and *rise* to the South, the *Streck* must be East; and



West. However, I acknowledge two things, for confirming that opinion.

First, that of all the *Coals* I ever have seen, where these contrary *dipps* and *risings*, could not be traced, and made visible, the *Streek* hath inclined to those points of South and North. But I must also confess, that they are but few I have seen, in respect of what I have not seen, and so if any others experience, who have seen more, contradi<sup>c</sup>t mine, I shall willingly yeeld, and not be tenacious.

Next, in these *Coals*, which I instanced, that have their *Cropp* to all the Points, and consequently their *Streeks*, and in others of the same nature, which I have seen, and not instanced, I found that part of the *Streek*, which lyes towards these *Cardinal points*, to be the greatest, being double, or triple to the other *Streeks* in length. So that when the *Streek*, that lyes either along the one *Cropp*, or the other, towards the S W, and N E, will be seven miles in length, that lying S E, and N W, will be but four, and sometimes less. And this is all the account I can give, of that part of *Coal*, called the *Streek*.

The second thing I promised to speak of, was of some things, which are but accidental to *Coals*, and yet so ordinary, that hardly are any found without them in lesser, or greater degree, such are *Gae's*, and *Dykes*, which alters their natural *course*, and they being the occasion of so much *Trouble*, in the working of *Coal*, and following its *course*, the *Coal-bewers* call them ordinarily by that name *Trouble*. This *Trouble* or *Gae* then, is a Body of *Metal* falling in upon the *course* of the *Coal*, or *Free-front*, obstructing, or altering their kindly and natural *course*, keeping no regular *course* it self, and being of nature alwayes different from the *Metal*, whose *course* it interrupts. And these *Gae's* differ

fer also among themselves, in their nature, and in their *course* they keep: or more properly in the way wherein they encounter other *Metalls*, and in their effects. In their nature, for some of them consists of an impregnable *Whin-Rock*, or *Flinty-Stone*, thorow which it is almost impossible to work: and if there be a necessity to cut them thorow, it is done at a vast expence, and takes a long time, and must be cut open to the surface of the earth, it being impossible to Mine it under ground. Some of them are again of *Stone*, like a *Free-stone*, but seems rather an abortive of nature, they having no rule in their *course*, by which a man can follow them, nor can their stone be useful.

In their encountering of *Coals*, or *Free-stone*, sometimes they encounter them in the *Dip*, and sometimes in the *Streek*, and sometimes between the two. These that are met with in following the *Dipp* of the Coal, ly along the *Streek* thereof. For example, if the *Coal Dipp* SE, the *Gae* lies NE, and SW. These that are encountered in the *Streek*, lyes to the *Dipp* and *Rise*: so the *Coal Streek* NE, and SW, the *Gae* is found to ly SE, and NW. Others of them, lyes between *Streek* and *Dipp*, that is to some point between the two: as the *Streek* being SW, and NE, and the *Dipp* and *Rise* SE, and NW, there may be a *Gae* found lying WSW, and ENE. Now, when I speak of a *Gae's* lying to such Points of the Compass, this doth not contradict what was said before, that they had no regular *course* themselves. My meaning being, that though they have a certain length, lying between two points, and a thickness between two *Metalls*, yet by the *Metal* of the *Gae* it self, it is impossible to know its *course*, as it is in other *Metalls* of *Coal* or *Free-stone*, whose *courses* are discernable at the first view.

Their

Their effects are different, as their nature and *course* are different: only they agree in these two generals. First, that all of them renders that part of the *Coal*, that comes nearest to them, unprofitable and useless, though some less, and some more, they being unfit for burning. And it is remarked, that these *Gaes* that consists of *Whin-rock*, renders the *Coal* next to it, as if it were already burnt, being so dried, that it moulders in handling it. In others, the *Coal* is not altogether so ill, and yet its nature is altered, from what it is at a distance from the *Gae*. The next general is, that all of them alters the natural *course* of the *Coal* in less or more, some of them making it *Dipp* much more than its ordinary *course*, which they call *Down-gaes*: Some again making their *rise* much more than their *course*, which they call *Up-gaes*. Others making an alteration as to the *Streack*, causing it go out beyond its ordinary bounds, as we observed before in that great *Streack* of *Coal* between *Preston-Grange* and *Stobhill*.

Now it is to be considered, that when in working of a *Coal*, whether to the *Dipp*, or *Rise*, or *Streack*, one of these *Gaes* is encountered with, the *Coal* is quite cut off, and as it were *terminat*: so that you see nothing where the *Coal* should be, but either a *Stone*, or *Clay*, or rotten *Pill*, or some such thing. And the practise of *Coullery* is to trace the *course* of the *Coal* through that, till you overtake it in the other side. And before any thing be said to that part, you must notice, that some *Gaes* are of greater force than others, and their influence upon the *course* of other *Metals* greater, whence you shall see a threefold effect. One is, that by some great *Gaes*, which a *Coal* meets with, it is quite cut off, so that in the other side thereof, there is not a vestige of that *Coal*, or of any other *Metal* that was

above

above it; or below it; to be seen. And if there be any other Coal, as sometimes there are, they are quite different from them of the other side. I said by *some*, because there is one instance to the contrary, which is somewhat singular. In the Earl of Winton's ground at Gochony, there is found a course of Coals, and Free-stones dipping to the S E. in the Link; and upon the full-sea-mark, there is a tract or course of Whin-rocks lying E and W, underneath which these Coals and Stones comes thorow without alteration of course, and are found within the Sea-mark, with the same Dipp and Rise upon the North side, they liad upon the South side of the said Rocks: and yet the Coal is encountered upon the South hand by a Gas under ground, through which it passeth, not without a considerable alteration.

The greatest of these Gases, that I know, is that which takes its beginning, that we see on Land, at the Harbour of the Pans, called Achifons-Haven, which hath been cut by Preston-Grange, for Level to his Coal, and goes from that to Seaton, which may be traced above ground, almost the whole way, and hath been cut at Seaton for serving the Level of that Coal now wrought at Tranent. From thence it passeth through the fields of Dong-Niddry, a place pertaining to the Earl of Winton, and through the Cair, which pertains to the Earl of Haddington, till it joyn with Pancrath-hills, a tract of Rocky Mountains, from whence it is traceable to Linton-bridges, where it is visible in the Water, the Water of Tyne falling over it, and making a Lin, which they call Linton-Lin, from thence to the East-sea. And it is known by Sea-men, that it keeps a course thorow the Firth from Achifons-haven, (whence we reckoned its beginning upon Land) towards the West  
and

and N W, it being found to the Southward of *Inch-keith*, and before *Leith*, where stands a *Beacon*, and so can be traced to the North Shore.

The second effect of *Gaes*, is to cut off the *Coal* quite, as to a part of the field, so that in the other side, having pierced the *Gae*, you shall not find the *Coal*, and possibly not within a quarter of a mile of the *Gae*, which cuts it off, and at that place shall only find the *Cropp* and the *Body Dipping*, as it did before it was cut off, and if you shall measure between that side of the *Gae*, where you lost your *Coal* (I suppose the *Coal* then being 24 fathom from the *Grass*) to the place where the *Coal* in the other side of the *Gae* shall be found at the same deepness, it will be near 500 paces. For making this more intelligible, let us suppose a *Coal Dipping* S E, and in working to the *Dipp*, there is a *Gae* encountered with (This was really done in a piece of ground I know, and so it is no meer supposition) at which *Gae* the *Coal* is cut off; for finding whereof the *Gae* is pierced, and nothing found in the other side, viz. in the S E side of the *Gae*, but at more than 100 paces distant, the *Crop* of a *Coal*, which lyes under the *Coal*, that was lost, was found; after which it was easie to find the other. Now, that it was the same *Coal*, that was lost, upon the North side of the *Gae*, is not only evident, by the kind of *Coal*, and all the *Metals* above, and below keeping the same course, but by this, that the *Gae* wearing out towards the West, the two parts of the *Coal* that was separated by it, joyne themselves again, and continues in one body, as they were before separation.

The last effect of the *Gae* is, that it doth not quite cut off the *Coal* from the other side of it, but makes an alteration in the course, either in the *Dipp*, or in the *Rise*, or  
*Street*,

*Streek*, as was before noted: so that in meeting with one of these *Gaes*, having considered its nature, and pierced it, the *Coal* will be found in the other side, immediately touching the *Gae*, but with an alteration of *course*. Now, in these two last effects, since the *Coal* is not totally cut off, it will be worth the inquiry, to find the surest way of recovering the *Coal* after it is lost. Therefore, where the *Coal* is not cut off, by a considerable distance; and having pierced the *Gae*, it is not to be found in the other side, you are to consider well the nature of the *Metals* you find approach to the *Gae*, and if they be such, whether *Stone*, or *Coal*, as you know to ly under the *Coal* that you have lost, then you may be sure the *Coal* is to be found above in its *course*, which is to be traced by the *Dipp* of the *Metals* you find. As sometimes I have seen, when a *Coal* hath been cut off by a *Gae*, happily there is another *Coal* under it 12 fathom, after the *Gae* hath been pierced, and the lost *Coal* not coming near to it in the other side, that hath been found there, by which it was certainly concluded, that the uppermost *Coal* behoved to be there also, though a little back, conform to its *course*. But, if the *Metals* or *Coals*, under the lost *Coal*, hath not been known, then you are to take notice of the *Dipp* and *Rise* of these *Metals*, you find on the other side of the *Gae*, which you have pierced, and making that your rule, *range back over the Metals*, conform to the direction to be given afterwards, and you shall find the *Cropp* of the *Coal* you want, and after which you were inquiring.

Where the *Coal* is not quite cut off by the *Gae*, but hath its *course* only altered, you are to consider, in searching for it, before you pierce your *Gae*, that which the *Coal-bearers* term the *Vise*, or some of them the *Weyse* of the *Gae*,



which in effect is nothing else, but a dark vestige of the *Dipp* or *Rise*, that the body which now constitutes the *Gae*, should have had naturally, if it had been perfected; which when it tends downward, then must the *Gae* be put over that way, and in the other side shall the *Coal* be found, and *Down*, as they term it; that is, the *Dipp* which it had naturally, augmented. And, if the *Rise* be *Up*, the same way must be taken for piercing the *Gae*, and the *Coal* will be found *Up*, that is, its *Rise* augmented. But these things cannot be made so intelligible, as by seeing, there being many things in the alteration of the *course* of Metals very curious, and worthy of Observation: as when a *Coal* is cast down out of its natural *course* by a *Gae*, and so made sometimes *under-Level*, it riseth as much to another hand, and the *Cropps* go so much farther out, which still makes the *Level* useful, the use whereof would have been judged lost by the *down-casting*. Sometimes a *Coal* made to have four contrary *courses*, as is evident from the eighth Figure, where there being a *Gae* at E, makes it take such another *course*, in stead of coming out to the *grafs*. Sometimes, before the Metals overtake the *Gae*, they are made to ly like a *Bow*, one instance whereof is visible above ground in some Metals lying between *Bruntland* and *Kinghorn*, at a place called the *Miln-stone*, where there is a small *Coal* with *Free-stone* above it, all *Dipping* to the S-E, and *Rising* to the N-W. Upon the *Rise* they meet with a *gae*, which is a great *Whin-rock*. In their *course* to the *grafs*, before they touch the said *Rock*, they take a contrary *course*, and *dipps* into it, and are there quite cut off. The manner whereof is to be seen in this tenth Figure following.

Figure

Figure 10.



Where AB is the *Rock*: EF the *Coal*: CD the *Free-stone*. Now, whereas they should have risen towards A, they turn at D, and *dipps* into the *Rock*, which any may observe in passing that way. Many other such motions are observable, which I pass, and leaves them to the observation of the curious.

The third thing I promised to speak of, was of *Damps*, and as they are termed by the *Coal-hewers*, *Ill Air*. These do-deserve a more accurat inquiry into their *kinds*, their *causes*, and *effects*; then I am capable to make, there being many things in them very considerable, and worthy of a narrow search: therefore following the course I have hitherto observed, I shall shew my own Observations thereof, and leave the more curious search to the spirits fitted for that purpose.

This *Damp* then makes an obstruction of respiration in Men, or other living Creatures, in Subterraneous spaces, as *Caves*, *Coal-rooms*, *Levels*, *Sinks*, and such like; which obstruction proceeds principally from two causes, both which goes under the name of *Ill Air*, among the vulgar. The first is the corruption, or putrefaction of the Air, whereof there are two sorts; one is in places where

hath been *fire* kindled, which burns the *Coal* under ground, the smoke whereof, being full of Sulphur, and other Bituminous matter, and not having free passage to come above ground, filleth all the *waste Rooms* under ground, and infects the Air so, that the smell of it, even at a distance, is intolerable, and amongst it no living Creature is able to breath. Of this there are examples in *Dysert in Fife*, and *Fauside in East-Lothian*. This was kindled on design by a Fellow, who for his pains was hanged in the place, and hath burnt these 50 years, and more, the *fire* whereof is sometimes seen near the *grass*, with abundance of smoke, as it runs from one place to another. The second, where the Air is corrupted without the mixture of smoke, or any other gross corrupting body, which is the most considerable of all *Damps*, and hath the strangest effects, in killing *Animals* in an instant, and so hath been alwayes most prejudicial in the works, where it is found, many persons having thereby lost their lives, without access to cry but once *Gods mercy*, to some instances whereof I have been witness. I shall not offer to determine about the cause of this *Damp*, but shall give an account of somethings I have observed about it, which when duely pondered, may happily lay a foundation, at least of a probable conjecture, whence it may proceed.

This kind of *Damp* then, and *Ill Air*, is never found in *Coal*, or other *Metals*, where there is Water to be found; I mean, whence the Water hath not been drawn away by a *Level*, or *Aqua-duct*: as in *Coals*, where there is a necessity to *lave* the Water from place to place, or to pump it along the ascent or rise of the *Coal*, to the bottom of the *Sink*, from which it is drawn out above ground, this *Ill Air* is not found. Nor is found frequently, if at all, in these

these *Coals* where the Water is drawn from the *Coal* by a *Level*, or *Aqua-duct* under ground, till it come of its own accord to the bottom of a *Sink*, which is in place of a *Cistern*, out of which it is forced also above ground, and differs only from the other, that the Water runs here of its own accord by a descent to the *Sink*, which is termed a *drawing Sink*: in the other it must be forced by the *Rise* of the *Coal*, because haply, a *Sink* upon the *Dipp* would be of such a *deepness*, that no force could draw it up in a perpendicular.

But this kind of *Damp* is found ordinarily in these *Coals* from which the Water is drawn by a *Level*, the beginning or mouth whereof is above ground, and carried along by a right Line under ground, till it overtake the *Coal*, which it is to dry: so that the Water which comes from the *Coal*, runs without being forced, and is sometimes so considerable, that it makes *Mills* go, without any other addition, as is to be seen in the Earl of *Wintons* Lands of *Seton*, where four *Mills* goes with the Water that comes from under ground, out of the *Coal*; which kind of *Levels* are only found where the *Coal* lyes in a Field, which hath a considerable *Rise*, or ascent above ground; there being a necessity to make use of the other two wayes spoken of, for drying the *Coal*, when the Field in which it lyes is a Plain.

Further, of these *Coals*, which are dried by the *Free-level* (for so they term the *Level* that runs unforced) there are some to which this kind of *Damp* is more incident, than to others. The cause of which difference is found to be, the solidity and closeness of the *Metals*, whether of *Coal* or *Stone*, wherein some exceeds another. There being some, that are full of *rifts*, or empty spaces ( I mean empty

empty of any part of the same body where they are) which will sometimes serve, to convey a considerable quantity of Water in place of an *aqua-duct* or *level*, which *spaces* are termed by the vulgar, *Cutters*, which sometimes proves very profitable in the ground where they are found, both in regard of the use they serve for, in stead of *Level*, and for rendring the *Metals* wherein they are found, more easie to work, in making them yeeld easily to the force of the *wedge* and *lever*. Other *Metals* there are, wherein few of these *Cutters* are to be found, and if water be to be conveyed through them, there is a necessity of cutting a passage through them for that effect. Now, this *Damp*, whereof we speak is found most frequently, and most violent in the first sort of *Metals*, viz. in these which are full of *Cutters* or *Rifts*, which gives some ground to this conjecture of its cause. These *Spaces* which are found in *Coal*, or other *Metals*, as *Stone* or *Till*, before the *Coal* begin to be dryed by a *Level*, are full of water, which is still in motion, as are all *subterraneous springs*, whereof some are more violent, some more slow, conform to the passage they have to the fountains above ground, where they discharge themselves. Now, for drying these *Coals*, and rendring them workable, there is a necessity to cut a passage, thorow which that water discharges it self quickly, it being large, and admitting a great quantity at once, by vertue whereof, a great field is drained at once, and the *Source* not being able to furnish so much water, as the *Conduit* is able to convey, these *Spaces* in the body of the *Metals*, being emptied of Water, must needs be filled with *Air*, which *Air* having little *contact* and *commence*, with the great body of *Air* above ground, and so hath little or no motion, corrupts in these places, and thereby becomes  
*poisonable*

poisonable, so that when any *Animal* is necessitat to draw it, and *respire* by it, it choaks them on a sudden, just as standing Water, which being without motion corrupts, and becomes poisonable, though haply not in so great a degree as the *Air*: the *Air*, being a body much finer and purer, than Water, that holding good in it, *corruptio optimi pessima*. This is much confirmed by what is before asserted, that in the *Coals*, whence the Water is drawn, and they drained, but not by *free-course*, but by *Force*, as *Pumping*, and drawing by *buckets*, these *Damps* are seldom or never found: because the passage of the Water being forced, it does not so suddenly dry the *Metals*, as the other, whereby there is alwayes left in these *Spaces* some Water, which being it self in motion, keeps the *Air* also in motion with it, and thereby the *Air* is kept from *corruption*, at least in such a degree, as it is in the other. Hence we find, that in these kinds of *Coals*, the *Rooms* under-ground are alwayes wet, or for the most part they are so: whereas in the other, there will be no Water found to wash a mans hands: and sometimes the *Coal* through want of Water, becomes so dry, that it cannot be wrought in great pieces, as others, but crushes in the very working, and when wrought, is rendered useless, and will not at all burn. This puts me in mind of a very pleasant conception of a worthy and learned Person, Doctor George Hepburn of Monk-ridge, with whom I had occasion one day to discourse on this Subject. He is of opinion that the *Water* is the *Mother* of the *Coal*, whereby it is preserved fresh, and incorrupted, and that when the *Water* is drawn off, and this *Damp* follows, it is not the *Air*, which succeeds in place of the *Water*, and is corrupted for want of motion, that occasions it. But as we see, when the corruption of a Li-  
quor



quor within a Vessel, when the *Mother* is gone, corrupts the Vessel it self, and occasions an ill savour or taste in the Vessel; so that the *Coal* being corrupted by the want of its *Mother*, the *Water*; corrupts the *Air* in the subterraneous *Spaces*, as in *Coal-Mines*, *Sinks*, *Caves*, and other such like. He had likewise another pleasant conception about the *generation of Coal*, judging it to be formed gradually out of another Metal, as, of *Till*, by the help of *Water*; of which he himself may perhaps give an account. And though I be not of his opinion in that matter, yet I must acknowledge, I was taken with it, and shall be glad to see a more full account of it from him, than he had access to do in the short conference we had.

The effects of this *Damp* are first, it hinders the burning of all combustible matter, as *Candle*, *Coal*, *Pitch*, *Sulphur*, &c. so that if you take a *Torch* lighted, and let it down to a *Sink*, where the *Ill Air* is prevalent in the time, it shall straightway extinguish it. Or take a *Coal*, which is burning, and let it down, it shall not only extinguish the *Flame*, but shall make the *Coal* in an instant *dead*, and as cold as never heat had been in it. But the most dangerous effect is, its killing of *living Creatures*, whereby many persons have been suddenly killed. Some in going down to a *Sink*, where it hath been powerful, have fallen out of the *Rope*, and perished. Others have been choaked, and yet have gotten out by the help of others in a sudden, and have remained a considerable time without the least appearance of life, but yet have at last recovered. Yet it hath been observed, that some of these persons that have been so struck with the *Damp*, and recovered, have had alwayes some *lightness of Brain* thereafter, and never so settled as formerly. This I know to have happened to one, whom I have seen so, many times thereafter. What

What hath been its effects on some *Animals*, whereof you have made Experiment, I leave to the account you have given. One thing I shall only mention, which to me seems somewhat strange, that notwithstanding these *Damps* are so effectual, and causeth so suddenly the death of *Animals*, yet the *Ratts*, which are in some of these places, where the *Damps* are most violent, are not reached by them. For sometimes, when they are so powerful, that nothing that lives can enter under ground, without sudden death, yet they continue there, and are not found to diminish, even where they have no access to escape, by coming above ground. Or if it should be imagined, they removed to some other place of the ground, where the *Damp* is not, how is it, they are not as quickly choaked with it, as *Dogs* are, and other *Animals*, which at the first encounter are killed?

If it be inquired, how comes it to pass, that in these Fields of *Coals*, which are dried fully (as was said) and to which these *Damps* are incident, because of corrupted Air that remains within the Body of the *Coal*, or other *Metals*, how comes it to pass (I say) that they are but sometimes incident, and are not alwayes found? For clearing this, it is certain, that even in the grounds, where these *Damps* are most frequent, for the reasons above mentioned, yet they are only powerful when the Wind blows from such a certain *Point*, as some Chimneys, that do only smoke, when the Wind is in such an *Airth*: This is so generally, and well known, that the *Work-men* observe it, and when they find the Wind in such a *Point*, whence they fear the *Damp*, they will not enter under ground, till trial be made of the Air, which they do in *Sinks*, by first let-

ting down a lighted *Candle*, or some burning *Coals*: which if they do not burn, then there is no access to enter.

Secondly, the wind in which this *Ill Air* is most noxious, and hurtful, blows from that Point, where the Field of *Coal* lies, that's not yet wrought, which seems somewhat strange, and yet when duely considered, it will appear abundantly consonant to reason. An example of this is to be found in the *Coal* of *Tranent* and *Elphinston*, the *Street* whereof goes to the *rise* of the Hill above ground, from NE to SW, as hath been formerly observed. So that the beginning of their *Level*, is at the NE point of the *Street*, from which the *Coal* hath been wrought up along the *Street* towards the SW, the *Wastes* lying all towards the NE. Yet when the Wind blows from NE, or N, or almost from any other Point of the Compass, they are not troubled with this *Damp*. But if it blow from SW, and blow hard, they are in hazard to encounter it. And though the *Damp* is not alwayes found when that Wind blows (whereof there may be some particular cause) yet it is never observed in another Wind, whether it blow less or more: the reason whereof may probably be, that the Wind blowing from other Points, as from N, or NE, hath more access to enter the *Wastes* under ground, and move the Air that is in them, towards the face of the unwrought *Coal*, whence is supposed to proceed the corrupted Air, that lurks in the *Rifts* and *Crevices* thereof, (from which the Water is drawn away,) and occasions the *Damp*. Now this Air being moved by the force of the Wind, keeps the corrupt Air from coming out, it being stronger then the other. Whereas, upon the contrary, while the Wind blows from SW, it entering the empty *Rooms*, drives the Air under ground from the face of the unwrought

wrought *Coal*, down towards the *old wastes*, which have their *course* from the beginning of the *Level*. By which means, the *Air*, that is corrupted within the bowels (to speak so) of the *Coal*, comes out to the *Wastes*, without resistance, it being certain, that *Fluid Bodies*, as *Water*, and *Air*, inclines to move towards that place, where they meet with the least resistance. Hence is it, that the more direct the Wind be, in blowing against the face of the unwrought *Coal*, as is the Wind from N E, the *Ill Air* is the more repelled and driven back, but the more oblique it be, as are the Winds from these Points, that are nearest to S W, the *Air* is not so good and free: which difference is known by the burning of *Candles*, they burning with greater difficulty in these Winds, than in others, which blow from these Points nearest to N, and N E. Some are of opinion, this *Ill Air* (in those places we have been speaking of) comes from the great *Wastes*, that ly above the unwrought *Coal*, and by strong S W Winds is driven thorow the *Cutters* thereof. Or the Wind blowing from that Point, and coming thorow these *Cutters*, brings the corrupted Air alongs with it, even as, after a shower of Rain, a spait of Water comes, and carries alongs with it, both the foul Water and the clean, it meets with. Though this may be probable, which seems to be your own opinion, yet the other seems to be more probable.

The other sort of *Damp*, is that which they call *want of Air*; and though the term be not altogether proper (there being no space without some Air) yet there is a want of Air, which is sufficient for respiration of *Animals*, or for the burning of fire. This is ordinarily found in the running of *Mines* under ground, for conveying of Water from *Coal*, or other *Metals*, or in the *waste Rooms* of *Coals*, where

the *Sinks* are very deep, and to evite the charge thereof, there is some necessity to work as far under ground for winning of *Coal*, as is possible, without new *Sinks*. The cause seems to be, that the Air under ground, in such cases, wants communication with the Air above ground, because it is found, that by giving more communication, the evil is cured. Whence comes the necessity of *Air-holes* in *Levels*, which are so many *Sinks* set down, for no other use, but for giving Air to the *Workers*. Some are of opinion, that this defect might be supplied by the blowing of Bellows, from above ground, through a Stroop of Leather, or of some other thing, which must run along to the end of the *Level*, for keeping the Air there in motion. But I have not yet heard, that it hath been made practicable.

The effects of this *Damp* are not so dangerous, as these of the other. 'Tis true, it will kill Animals, and extinguish burning *Coals* and *Candles*, but not so suddenly as the former; and so people are not so readily surprized by it. The other seems to kill by some poisonous quality: in this *Animals* dies for want of sufficient Air for respiration. Therefore in advancing in a *Coal Room*, or *Level* where this is, you shall see the flame of the Candle grow less and less by degrees, till at last it be totally extinguished, and the person entering, shall find the difficulty of breathing grow greater, as he advanceth forward, till at last he cannot breath at all. Hence it is, that few or none are killed by this kind of *Damp*, and all its prejudice is, that it renders the work more chargeable, when there is a necessity to remove it.

For that, which they call *Wild-fire*, it being a thing not incident, but to very few *Coals*, is less known, than any of the rest of the accidents that follows *Coals*. The account

count I have heard of it, is, that in some *Coals*, which naturally are full of *Oil*, and that are (as they call them) *fatt Coals*, there is a certain *Fire*, which is as a *Meteor*, and I judge, that from its resemblance to *Ignis fatuus*, which the Vulgar termeth *Wild-fire*, it hath the same name. It seems to be composed of some *fatt oily vapour*, that goeth out of the *Coal*, the *Pores* thereof being once opened, which is kindled after the same manner, as those fires above ground are, which are most ordinarily found in *fatt*, and *marrish* ground. Of this fire it is reported, that in the day time, while the *Work men*, are working in the *Coal-rooms*, it comes to no height, though it be sometimes seen in little holes of the *Coal-wall*, shining like kindled sulphure, but without force: but when the *Work-men* are once removed, and have stayed out all night, it gathers to such a strength, that at its first encountering with fire, which the *Coal-hewers* are necessitate to have, by taking in of light, it breaks out with such a violence, that it kills any person, it finds in its way. The reason, why it is without this force, while the *Work-men* are in the place, seems to be this, that they working with such violence, and motion as they do, do certainly move the *Air* considerably, it being contained in so narrow a place, as a *Coal-room*. And this *Air* being violented by motion, moves that *oily vapour*, whereof the fire is formed, so that it gets not liberty to unite itself, being dissipated by the motion of the *Air*. But so soon, as the *Air* is still, and quiet, after the *Work-men* are gone home, it unites it self, and gathers force, and therefore, so soon, as it meets with fire, which is more forcible, than the flame that is kindled in it, it rarifieth; the sulphurous parts being kindled, and forceth it self out, as powder out of a *Gun*. For it hath been observed, that if any person stay in the *Coal-*  
*sink*



*sink* while it breaks within the *Coal-room*, they are in danger of being killed. The ordinary way by which the hurt of it is prevented, is by a person that enters, before the *Work-men*, who being covered with *wet sack-cloath*, when he comes near the *Coal-mall*, where the *Fire* is feared, he creepeth on his belly, with a long *Poll* before him, with a lighted candle on the end thereof, with whose flame the *Wild-fire* meeting, breaketh with violence, and running alongs the *roof*, goeth out with a noise, at the mouth of the *Sink*, the person that gave fire, having escaped, by creeping on the ground, and keeping his face close to it, till it be over-passed, which is in a moment.

The place, where this was most known, was in a *Coal* be-west *Leith*, in a piece of Land called *Werdy*, which for want of *Level*, and the violence of that *Fire*, the *Owners* were forced to abandon.

I come now to the last part, which I promised to speak of, namely of the best way for trying of grounds, to find *Coal*, where never any hath hitherto been discovered, and of carrying on of *Levels*, for draining the Water of *Coals* and making it workable. As to the first part, there are but three wayes. First by *sinking*, which is most chargeable, in regard, that in such grounds, where the *Metals* are all intire, Water abounds, and this doth not only bring the *Master* under a necessity of great expence for drawing the Water, but also rendereth it impossible to get *sinked* to any deepness, which may suffice, for giving an account of all the *Metals* to be found, within the field, that may be rendred workable. There was a second way invented to supply this defect, which is by *boring*, with an instrument made of several *Rods* of Iron, which boareth thorow the *Metals*, and tryes them. This way in my opinion, is  
worse

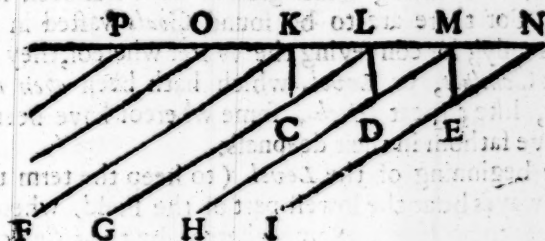
worse then the former. For first, if the *Coal* ly deep, in the place where you try by *boaring*, it becomes almost as tedious, and expensive, as *sinking*, the drawing of the *Rodes*, consuming so much time, in regard it must be frequently done. Next, in *boaring*, suppose the nature of the *Metals*, be found, yet thereby their *course* can never be known, till they be *sinked*, which is one of the things most considerable in the search of a *Coal*, because thereby is known, whether it be workable, with advantage or not, and whether it be possible to draw *Water* from it by a *Level*, or otherwise. Lastly, this way leaves the *Master* at an uncertainty (notwithstanding the *Coal* had been found) of its *goodness*, as to its *nature*, and as to its *thickness*. As to its *goodness*, because all that is found of the *Coal*, by this *boaring instrument*, is some small *drafs*, which remains after the wasting of the thing that's brought up in the *wumble*, by which none can judge of its *goodness*, or *badness*. As to its *thickness*, because it is impossible to discern exactly, when the *boaring-instrument* hath passed the *Coal*: all the rule for trying thereof, being the kind of *Metal* that is brought up in the *wumble*. Now, I have known in my experience a *Coal* *bored*, which the *Borer* by that rule hath judged four foot in *thickness*, yet when it came to be *sinked*, hath not proven one. The reason whereof, is obvious, because the *boaring-irons*, being long, and weighty in lifting them up, and down, they break the *Coal*, already pierced; and this falling down among the *Metals*, they are piercing, and being found in the *wumble* with them (especially when the *Metal* under the *Coal*, is a *black Till*) gives ground to imagine, that all that time, they have been piercing a *Coal*, and so consequently, the *Coal* must be of such a *thickness*,

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The last, and best way of trial, is that which is termed *an ranging over the Metals*. For doing whereof, this method, is to be observed. Suppose there be any place within the ground to be searched, where the course of *Metals* can be seen, as in the *banks* of a *River*, or *Rivulet*, or *Sea-banks*, when the place is near the *Sea*, then consideration must be had how far the lowest of these *Metals*, can go before they *Crop* out to the *Grass*, which will be known by observing the *Dipp* or declination of the *Metals*, and the *Rise* of the ground above, whereof a just allowance must be given, and having *digged* before the said *Crop*, you shall certainly find, the *Metal*, that is next under it, and if that prove not *Coal*, keeping the former proportion, you must advance, and *digg* before its *Crop*, and so shall you find, the next *Metal* under it, and so still, till you have tried your ground, and found the *Crops* of all your *Metals* within it. But if there be no *Water-banks*, or such like, to give you the first view, of the course of your *Metals*, then must you *sink* first at *random*, and having once past the *Clay*, you will readily overtake some *Metals*, whereby you will know the *course* of the rest, and having once found the *Dipp* and *Rise*, you must follow the method of *ranging* already prescribed, except the ground so to be tried, contains not within it self the *Crops* of the *Metals*, the body whereof lies in it, whether of *Coal*, or *Stone*, in that case, there is no way to try, but by *sinking*, or *boaring*. The way of *ranging* is conspicuous in the following figure.

Figure

Figure II.



The piece of ground to be tried, is P N, where there are several *Seams* of *Metals*, that *Cropps* out at the Points K L M N. Suppose the lowest to be the *Coal*, viz. I N, for which you are to make trial. You *Digg* first at K, without the *Cropp* of the *Seam* F K, and you *dig* till you find the other *Seam* of *Stone* G L, at the Point C. Following the Rule before given, you advance before its *cropp*, and *diggs* at L, and finds the other *Seam* of *Stone* H M, at the point D: from which you also advance, and *diggs* before its *cropp*, at the point M, and finds your *Coal* at the point E. But, if by advancing over the *cropps* of these *Metals*, which comes out from under one another, you find no *Coal*; then you are to range backward, for the *cropps* of *Metals* lying above these, where haply the *Coal* may be, as at O, and P. This in my opinion, is the most certain and exact way of trying Fields for *Coal*, or any other *Metal* of that nature, and least chargeable of all others.

The second of this last part, I promised to speak of, was in order to *Levels*, or *Coal-Mines*, which are nothing else, but *Conduits* or *Gutters* made under ground, for conveying of the *Water* from the *Coal*, and so rendering it

Pp

work-

workable. It seems that a very little time before this, that way of *Mining* under ground hath not been fallen upon. For there are to be found *Coals* wasted in their Croppes only; for conveying the Water whereof, they have made a *Conduit*, or *Level*, which hath been open to the Surface, like a great *Ditch*, some whereof have been ten or twelve fathom in their deepness.

The beginning of the *Level* (to keep the term used) must alwayes be at the lowest part of the Field, where the *Coal* lyes to be dried. Some whereof, by the rising of the ground, and the *Streek* of the *Coal* rising that way (as we shew before) gives the advantage of a *Free Level*, that is, when the Water comes above ground of its own accord, without being forced by drawing. In others, there is a necessity of *Engines* to draw the Water from the lowest part of the *Level*, and bring it above ground, which *Engines* are of several sorts. As when men draw with ordinary *Buckets*, or when there is a *horse-work*, or *water-work*, and that either by a *Chain* with *Plates*, and a *Pump*, or with a *Chain* and *Buckets*; all which are very common, especially those we have in *Scotland*, they being capable to draw but a very small draught, making only use of one *Sink* for that effect. But there are to be seen in the North of *England*, in *Bishoprick*, *Water-works*, by which Water is drawn above 40 fathom in perpendicular, but not all in one *Sink*. The manner whereof is thus, there being a *Sink* from the end of their *Level*, to the surface of the earth, where their *Works* are going, 40 fathom deep, which must dry the *Coal-Sinks* at 60 or 70, which ly above the *Banks* of the *River*, where the *Water-works* are situated, there is first one 40 fathom deep from the *Grass*. Another in a right Line from that, of 24. Another of 12; upon all which  
there

there are *Water-works*. In the first *Sink* the Water is drawn from the bottom 12 fathom, and thence conveyed into a *Level* or *Mine*, which carries it away to the second *Sink*. By the second *Work*, the Water is drawn out of the second *Sink* 14 fathom, from the bottom, and set in by a *Level* to the third *Sink*, which being only 12 fathom deep, the *Water-work* sets it above ground. The form of the *Engine* is after this manner. In the first *Sink* there is an *Outer-wheel* moved, as other *Milns* are, by the Water of the River: upon the end of the *Axle-tree* of which *Wheel*, there is a *Ragg-wheel*, turning *vertically*, as doth the *Outer-wheel*. This *Ragg-wheel* by a *Nutt*, or *Trinle* turns another, which moves *horizontally*, the *Axle-tree* whereof goes right down in the *Sink*, and may be is 8 or 10 fathom; at the end whereof there is another *Ragg*, which by a *Nutt* turns another *Wheel*, which goes *vertically* as the first *Ragg*, and causeth another *Wheel* with a long *Axle-tree* turn as the first, and so down till it come to the *Wheel*, which turns the *Axle-tree*, by which the *Chain* is drawn. The second *Sink*, hath such another *Engine*, but not so many *Wheels*, in regard it is not so deep. The third, hath only one *single Wheel*, whereby the Water is drawn above ground.

The most curious of these *Engines*, that are to be seen, are at *Ravensworth* near to *Newcastle*, which belongs to Sir *Thomas Liddel*, a most ingenious Gentleman, who, for procuring a *Fall* of Water, which may serve the *Wheels* of all the three *Sinks*, hath erected the first work upon Pillars like a *Wind-Mill*, pretty high above ground, from which the Water falling, makes the second go clost above ground. And to make the Water fall to the third, the whole *Wheel* is made go within the *surface* of the ground, which *terminats* at a *River* under the *Works*, which *Mine*



is of a considerable length. Where Water cannot be had to make such *Works* go, they use *Horse-works*, but not with so good success, being more chargeable, and not having so much force and power, as the *Water-works*. But I am of opinion, that *Wind-works* might serve well, where Water cannot be had; and when no Wind should happen to blow, the same *Works* might be supplied by *Horse*: and that the *Wind*, when it blows but ordinarily, hath as much force, as so much Water, which is made use of for turning such *Wheels*, is to me unquestionable. For I have seen in *Holland*, a *Wind-Mill*, that by the motion of the *Outer-wheel*, caused seven pair of *Mill-stones* to go at once, besides another motion for bringing the *Viſſual* from the ground, four or five *Stories* high, to be *Grund*. And several *Saw-Mills*, which besides six or seven great *Saws*, they caused go, did by another motion bring up from the *Water* great *Trees* like *Ship-Masts*, to be *sawen*, and placed them right against the *Saw*; all which could not be but of greater weight, than 10 or 12 fathom of *Chain* with *Buckets*, or *Plates* for drawing of Water.

But to return, for the right making of a *Level*, the true height of the ground, where the *Coal* lyes must be first taken, that it may be known, how much of the field can be drained by it; which must be done, either with a *Quadrant*, or with an Instrument made express. Then care must be taken, to take the lowest part for the mouth of the *Level*, that the field can afford, and from that it must be carried in a straight line towards that part of the field, where the *Coal* is thought to be encountered by the *Mine*. In working whereof, two things are in a special manner to be regarded. First, that the *Level* be wrought without *ascent*, or *descent*: the best way for trying this, being by the surface

face of the Water passing through it, which ought to be a little moving, as can be: for the loss of one foot of *Level*, which the ground gives, is a loss of a considerable parcel of *Coal* to be digged, especially if it be *flats*. If there occur any *Metals*, which are impregnable, in the *course* of the *Level*, so that it is impossible, to follow so straight a line, in regard the *Mine* must be wrought over the top of that stone, which is unworkable, in that case, there is but one of two to serve the loss of *Level*; either the *Coal* rises in *Streek* towards which the *Mine* is carried, and if that be, then after that *stone* is past, the *Level* must be carried, as low, as it was before it encountered the same, and the *course* of the Water shall not be obstructed; because the *source*, viz. the *Coal* from whence the Water comes, rising higher than the *Stone*, the Water shall easily pass over that height. Hence it is, that we see in some *Coals*, that have been wrought, at the lowest point of their *Streek* by a *drawing-sink*, and the *Streek* rising from that point, the Water that hath come off the *Coal*, being in its *Source* higher, than the mouth of that *drawing-sink*, hath made it to over-run, and serve to discharge all the Water, that comes therefrom. But, if the *Mine* be run to a *Coal*, that after it hath overtaken it, rises no higher in *Streek*, than the *Mine* it self, the Water that comes from it, will not pass over any height in its way, but will be unquestionably stopped. Therefore, in case such an impediment could not be removed, as many times such *Metals* will fall in, which are unworkable in a direct line, the use of a *Siphon* might be tried, which would unquestionably supply the loss of about 32 foot of *Level*, this being the height in Perpendicular, to which the *Pressure* of the *Air*, is able to raise Water up thorow a *Siphon*.

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The next thing to be observed in carrying on of *Levels*, are the *Air-holes*, for which there is a necessity indispensable. In setting down whereof, care must be had, that they be not directly upon the *Mine*, lest rubbish falling thorow from above ground, should stop, and obstruct the same, and so obstruct the *course* of the Water; and therefore it's better they be set down at a *side*, their only use being to communicate fresh Air to the *Work-men*, which if it could be otherwise supplied (as I think it not utterly impossible) would render the charge of the *Coal-works* a great deal more easy.

Other things might be spoken to of *Levels*, as that some run with the *course* of *Metals*, they pass thorow; and that some run against that *course*; and of bringing *Level* from the *Dip* of an *upper-Coal*, which hath a *Level* of its own, to dry a *Coal* lying under it, which cannot be otherwise done. But these things being common and obvious to any, who have but the smallest skill and experience, I shall forbear.

This confused account, your importunity hath drawn from me, for which if your *Book* suffer censure, which I grant it may do, as to this part of it, you are to blame your self, and so I rest and am, &c.



F I N I S.



